



Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-78

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**DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-78**

20 June 1996


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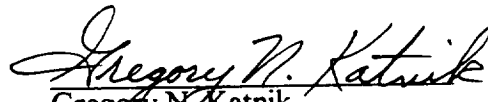

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

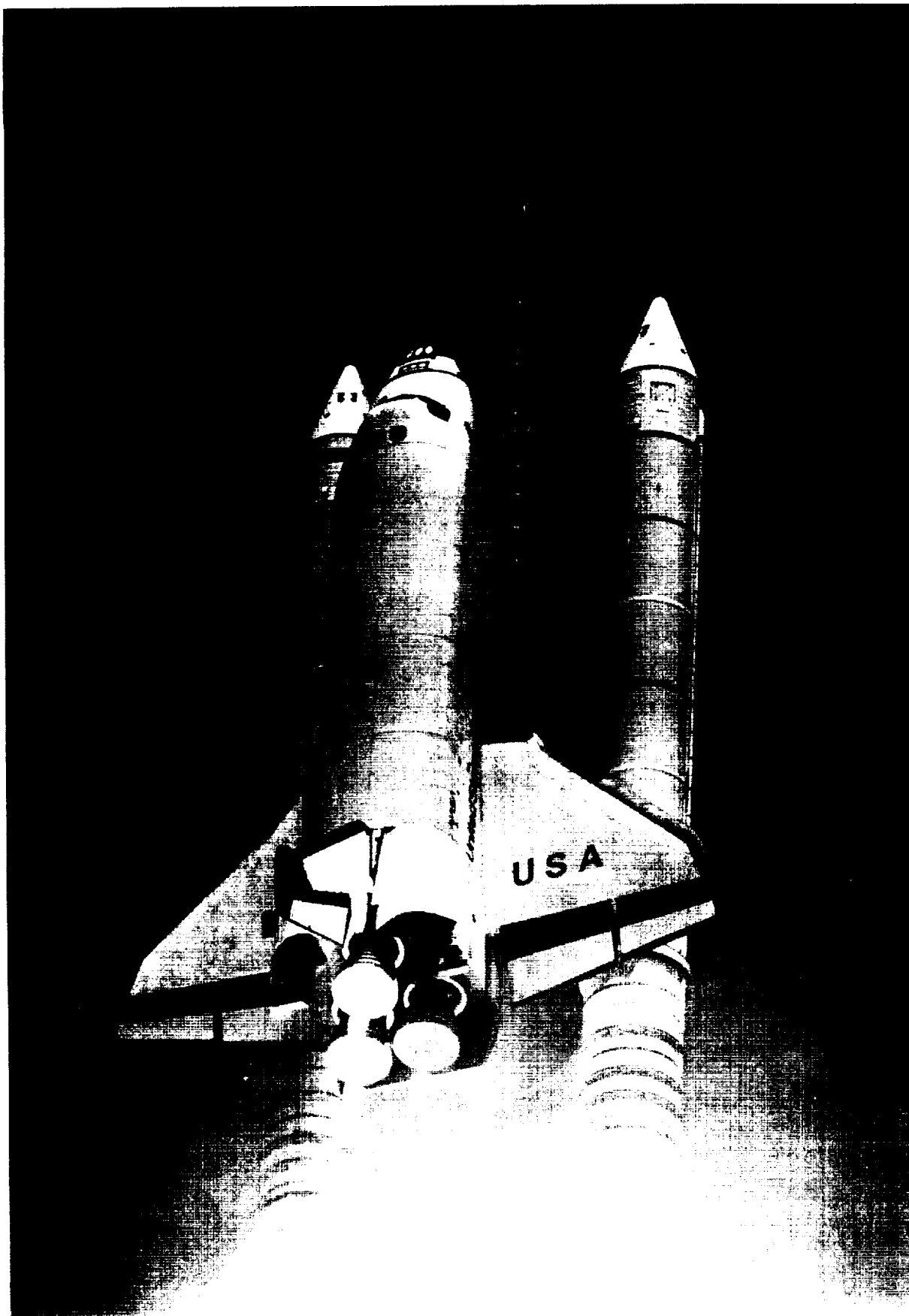


Photo 1: Launch of Shuttle Mission STS-78

1.0 SUMMARY

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 19 June 1996. The detailed walkdown of Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (20th flight), ET-79 (LWT 72), and BI-081 SRB's. There were no significant vehicle or pad anomalies.

IPR 78V-0134 documented K5NA trimmings from SRB IEA cover closeouts on both right and left aft booster stub rings and stiffener rings. Two pieces of K5NA, including the largest piece measuring 0.75-inches long by 0.75-inches wide by 0.50-inches thick, were within reach and removed by pad personnel. The IPR was dispositioned to fly as-is based on the debris location and highly improbable impact threat to the Orbiter. Examination of the IEA closeout revealed no flight hardware nonconformance condition.

The vehicle was cryoloaded for flight on 20 June 1996. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. No acreage icing or frost conditions were expected due to the late morning launch time. There were no ice/frost conditions or protuberance icing conditions outside of the established data base.

After the 10:49 a.m. (local) launch on 20 June 1996, a debris walk down of Pad 39B was performed. No flight hardware or TPS materials were found. All the T-0 umbilicals operated properly. Overall, damage to the launch pad was minimal.

A total of 105 films and videos were analyzed as part of the post mission data review. No vehicle damage or lost flight hardware was observed that would have affected the mission.

SSME #3 had a "cold start" causing the Mach diamond to form later than usual just prior to the SSME #2 Mach diamond.

A stud hang-up occurred on holddown post #5. Two semi-circular pieces of aluminum from the SRB aft skirt stud hole fell downward between the aft skirt and the holddown post #5 shoe. No ordnance fragments or frangible nut pieces fell from the DCS while in the field of view. The holddown post shoe lifted approximately 2 inches. No stud hang-ups or frangible nut/ordnance debris was observed on any of the other holddown posts.

Orbiter umbilical camera films showed nominal separation of SRB's from the External Tank and normal separation of the ET from the Orbiter.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The number of MSA-2 debonds on the right frustum was less than average. The number of MSA-2 debonds on the left frustum was somewhat greater than average with a large percentage of this number consisting of partial debonds on the leading edge of the fasteners.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-102 was conducted 7 July 1996 on SLF runway 33 at the Kennedy Space Center. The Orbiter TPS sustained a total of 85 hits, of which 12 had a major dimension of 1-inch or larger. Based on these numbers and comparison to statistics from previous missions of similar configuration, both the total number of hits and the number of hits 1-inch or larger was less than average.

The Orbiter lower surface sustained a total of 35 hits, of which 5 had a major dimension of 1-inch or larger. The largest lower surface tile damage site was located aft of the ET/ORB umbilicals and measured 2.5-inches long by 0.5-inches wide by 0.5-inch maximum depth. The damage was most likely caused by an ice impact from the umbilicals.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly.

The SSME #1 Dome Mounted Heat Shield (DMHS) closeout blankets were torn and frayed at the 7:00 o'clock position. Significant tearing and fraying to the SSME #3 DMHS blankets occurred from 7:00 to 12:00 o'clock. Although the face panels were still attached, some of the underlying batting material may be missing. The SSME #2 DMHS blankets were undamaged.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from the facility environment, SRB BSM exhaust, Orbiter RCS nozzle cover adhesive, Orbiter TPS, and paints/primers from various sources. These residual sampling data do not indicate a single source of damaging debris as all of the noted materials have previously been documented in post-landing sample reports. The residual sample data showed no debris trends when compared to previous mission data.

A total of nine Post Launch Anomalies, but no In-Flight Anomalies (IFA's), were observed during the STS-78 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 19 June 1996 at 0900 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

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3.0 LAUNCH

STS-78 was launched at 96:172:14:49:00.019 GMT (10:49 a.m. local) on 20 June 1996.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 19 June 1996. The detailed walkdown of Pad 39B and MLP-3 also included the primary flight elements OV-102 Columbia (20th flight), ET-79 (LWT 72), and BI-081 SRB's. There were no significant vehicle or launch pad anomalies.

DR DI-6-004162 documented a misaligned bolt hole on the B-2 camera position (film item E-7) due to a warped blast cover. The bolt could not be installed. Design Engineering evaluated the condition and determined the blast cover could sustain launch without the bolt. The hole was redrilled and a standard size bolt was installed after launch.

IPR 78V-0134 documented K5NA trimmings from SRB IEA cover closeouts on both right and left aft booster stub rings and stiffener rings. Two pieces of K5NA, including the largest piece measuring 0.75-inches long by 0.75-inches wide by 0.50-inches thick, were within reach and removed by pad personnel. The IPR was dispositioned to fly as-is based on the debris location and highly improbable impact threat to the Orbiter. Examination of the IEA closeout revealed no flight hardware nonconformance condition.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 20 June 1996 from 0605 to 0735 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. No acreage icing or frost conditions were expected due to the ambient conditions at this time of year. There were no protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, particularly those areas not visible from remote fixed scanners, and to scan for unusual temperature gradients.

3.2.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. Less than usual ice/frost had formed on the SSME heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.2.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the STI radiometers averaged 73-80 degrees F. Temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 73-78 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature supplied by THIO was 77 degrees F, which was within the required range of 44-86 degrees F.

3.2.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Final Inspection Team observed light condensate, but no ice or frost accumulations, on the LO2 tank. TPS surface temperatures ranged from 58-68 degrees F. An area of LO2 tank CPR measuring 3 degrees F less than the surrounding foam was observed using the infrared radiometer in the -Y+Z quadrant. The area extended from the LO2 tank-to-intertank flange to the ogive and was approximately 8 feet wide. However, no anomalies, such as ice/frost accumulation, were visible.

The intertank acreage exhibited no TPS anomalies. Ice/frost accumulation on the GUCP was less than usual.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost accumulation, was present on the acreage. TPS surface temperatures ranged from 53-66 degrees F. There were no anomalies on the new method bipod jack pad standoff closeouts. New foam (PDL-1034/SS-1171 alternate blowing agent foams) applied to the ET/SRB aft fairing closeouts, bipod jack pad closeouts, -Y ET/SRB aft fairings, and the LH2 umbilical cable tray appeared nominal.

Less than usual amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

No stress relief crack had formed in the -Y vertical strut forward surface TPS.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The summary of Ice/Frost Team observations/anomalies, which were all acceptable for launch per the NSTS-08303 criteria, included no OTV recorded items.

3.2.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch.

No leaks were observed on the GUCP or either of the LO2 and LH2 Orbiter T-0 umbilicals.

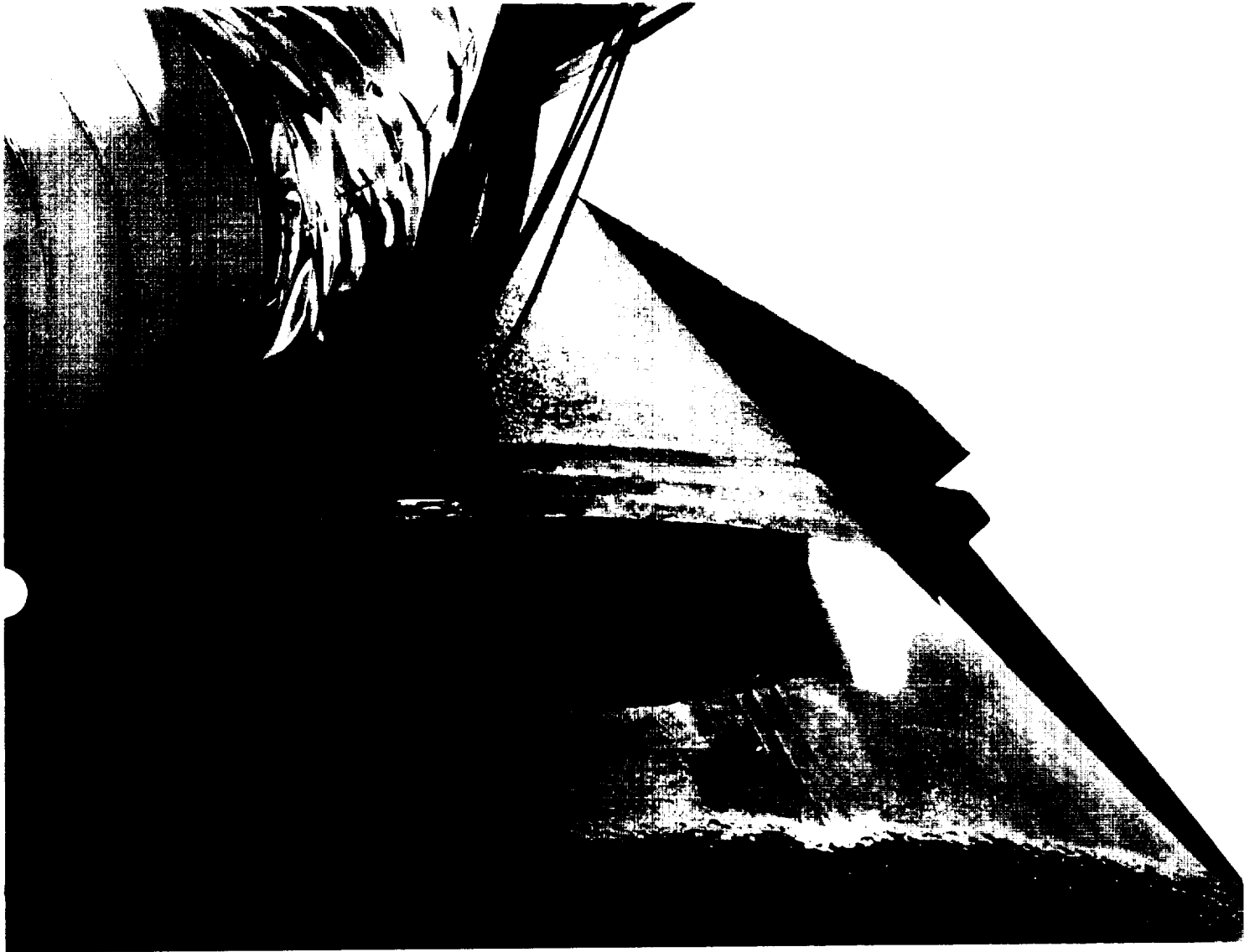


Photo 2: ET Nose Cone Topcoat Configuration

Loose topcoat was removed and the GOX vent seal footprint repaired/re-topcoated

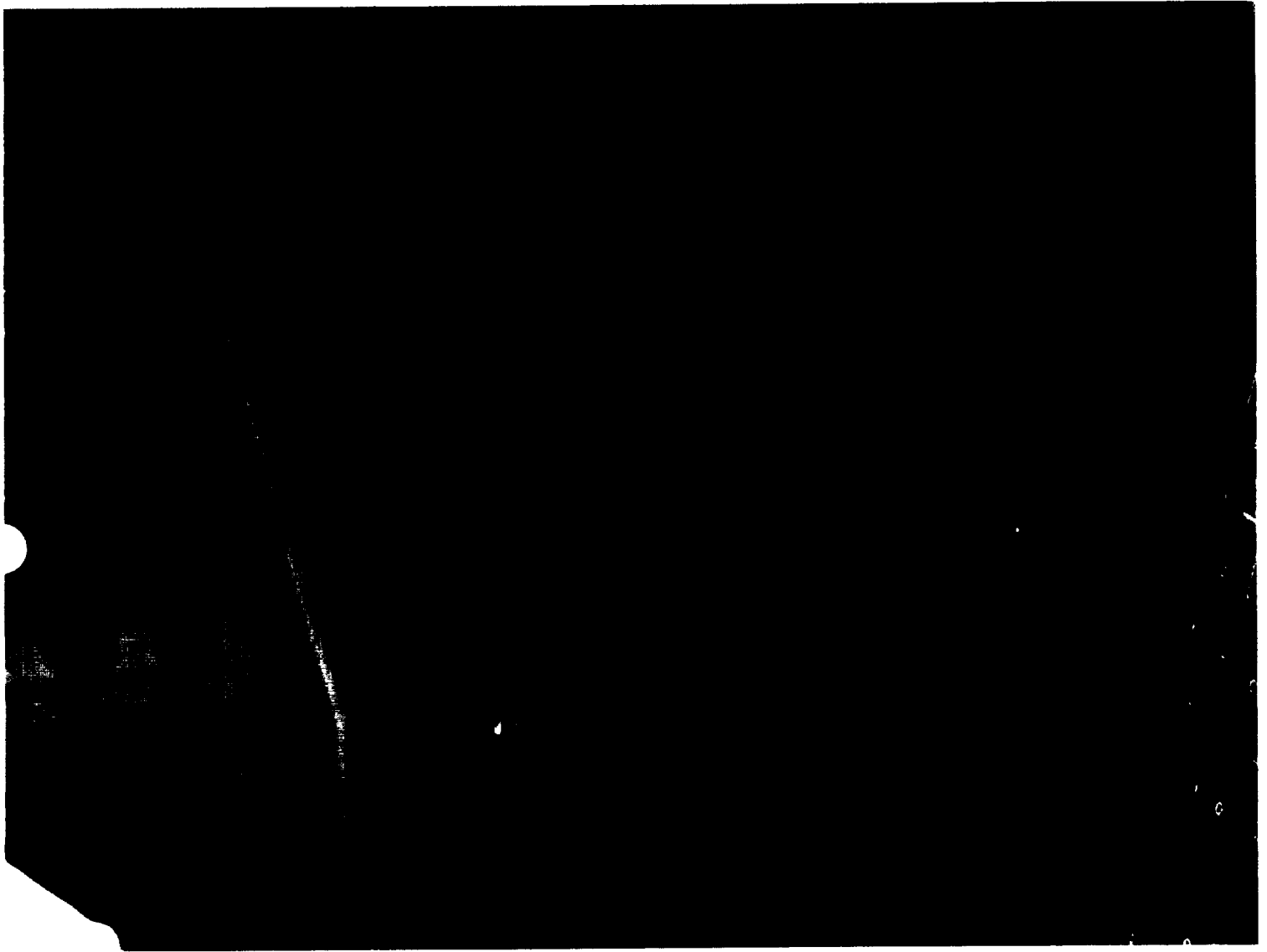


Photo 3: Bipod Jack Pad Standoff Closeouts

First flight of the new method jack pad standoff closeouts

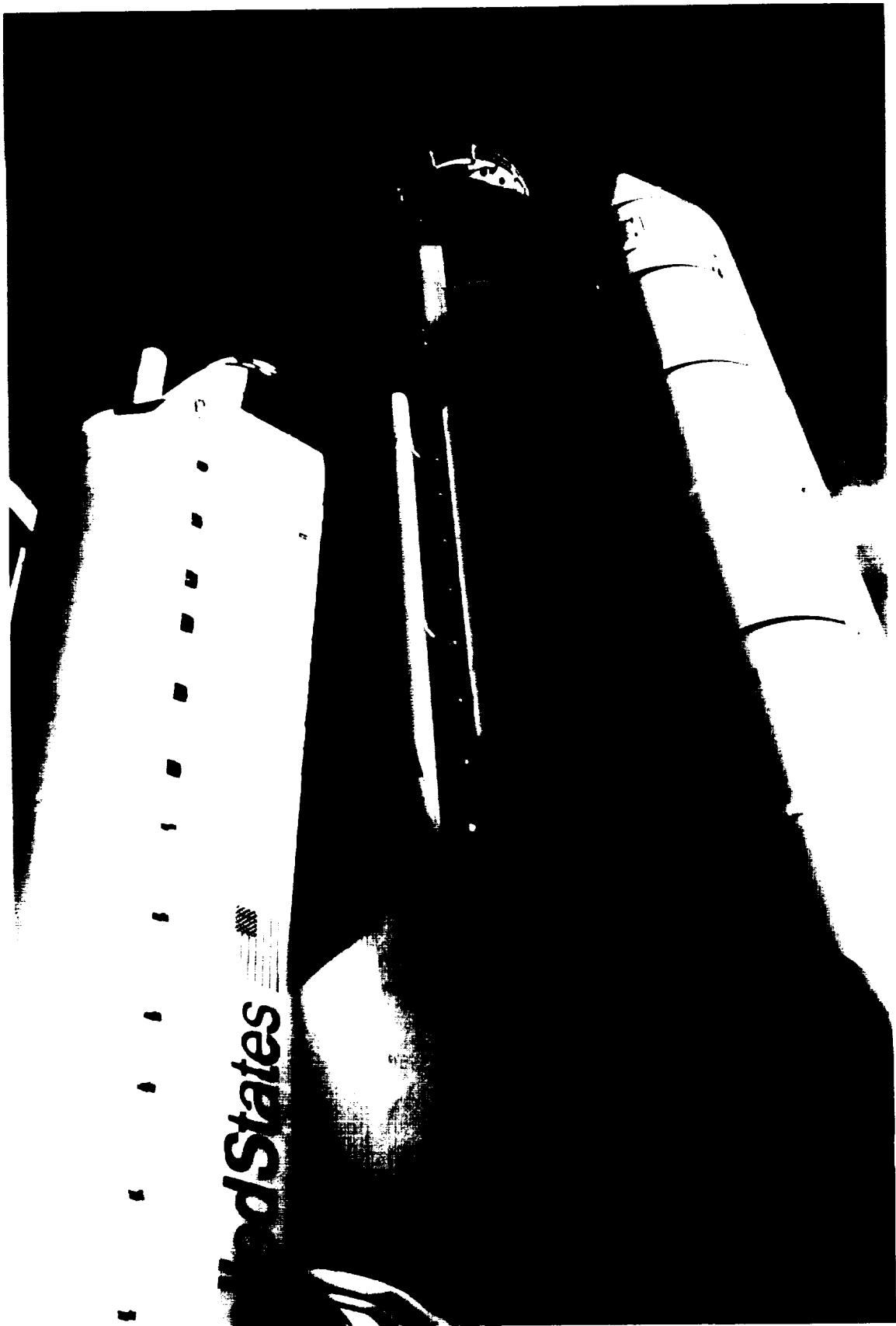


Photo 4: STS-78 Cryoloaded for Launch
OV-102 Columbia (20th flight), ET-79 (LWT 72), and BI-081 SRB's



Photo 5: ET-79 Cryoloaded for Launch

Light condensate, but no ice or frost accumulation, was present on the LO2 tank. TPS surface temperatures ranged from 58-68 degrees Fahrenheit

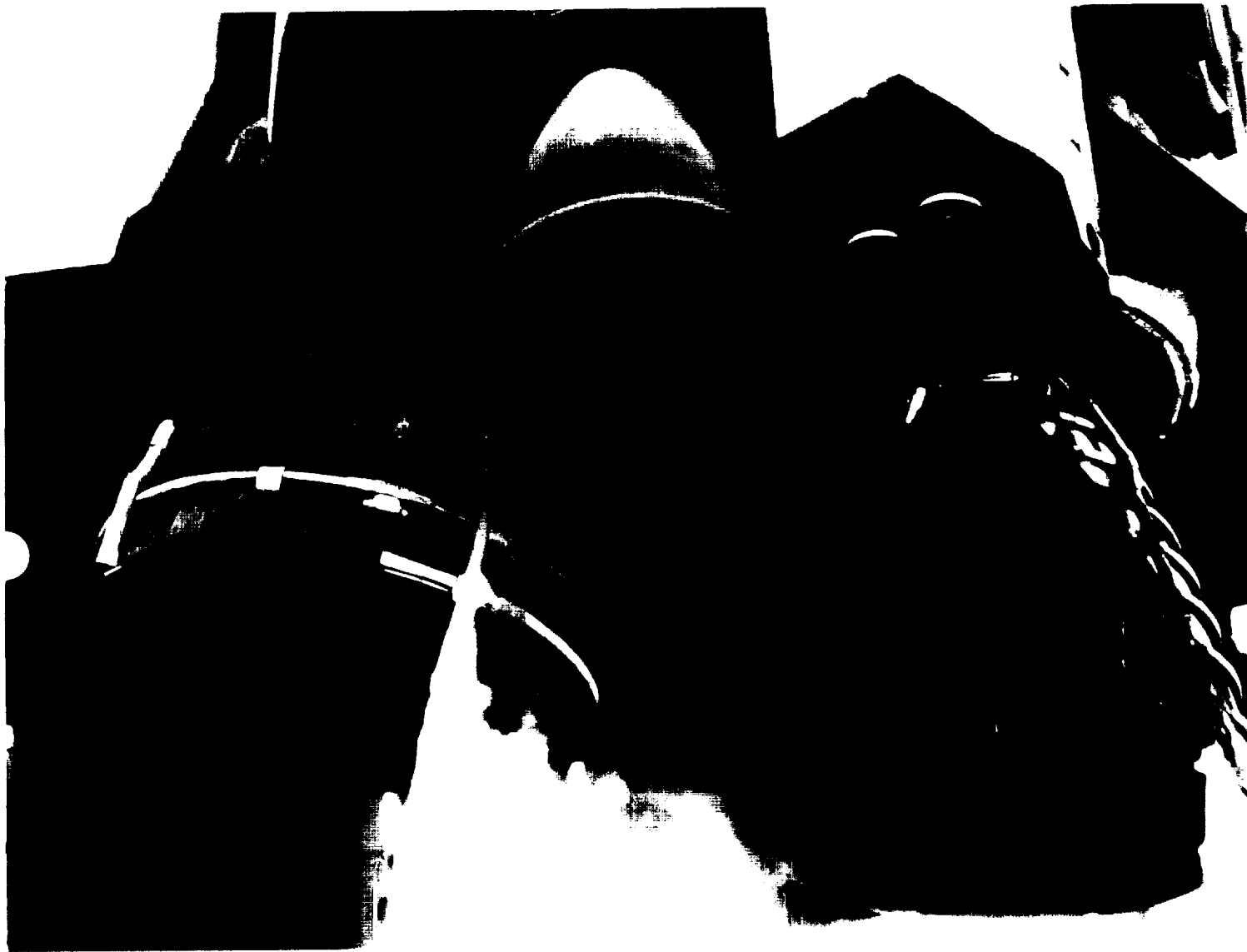


Photo 6: Overall View of SSME's



Photo 7: Orbiter Lower Surface Tiles

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, RSS, and Pad B crawlerway/acreage was conducted on 20 June 1996 for two hours starting at Launch + 2 hours.

No flight hardware or TPS materials were found.

South SRB holddown post and shoe erosion was typical. All south HDP shoe shim material was intact. A HDP stud hang-up was expected on holddown post #2 based on the observations of the post launch assessment team and the vehicle liftoff lateral acceleration of 0.30g's reported by Rockwell-Downey. Two areas of gouged/raised material were also observed on the edge of the HDP #1 stud hole. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was typical.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA) and GOX Vent Arm (GVA) appeared undamaged. No topcoat from the External Tank nose cone adhered to the GOX seals.

The GH2 vent line had no loose cables (static retract lanyard), and appeared to have latched properly with no rebound. The GUCP leg crossbeam showed signs of contact by the static retract lanyard. The vent line was latched on the seventh tooth of the latching mechanism. The RSS cable had disconnected properly.

Typical pad damage included:

- Two broken lights on the pad northeast slope

- Damaged cable tray panel cover on the FSS 115 foot level

- Metal strap from OIS box on FSS 135 foot level

Overall, damage to the pad appeared to be minimal.

Post launch pad inspection anomalies are listed in Section 9.

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or IFA's were generated as a result of the film review. Post flight anomalies are listed in Section 9.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 80 films and videos, which included twenty-six 16mm films, fifteen 35mm films, and thirty-nine videos, were reviewed starting on launch day.

SSME #3 had a "cold start" causing the Mach diamond to form later than usual just prior to the SSME #2 Mach diamond (E-63).

A noticeable amount of free burning hydrogen drifted upward and outboard of SSME #2 during ignition (E-16, -18). Free burning hydrogen drifted upward from SSME #1 to the OMS pod (OTV 151, 163, 170, 171).

Three light spots on the SSME #3 hatbands and drain line were attributed to sunlight on the nozzle (E-19).

Small pieces of tile surface coating material were lost from 4 places on the base heat shield near SSME #2 (E-18).

SSME ignition caused pieces of ice to fall from the ET/ORB umbilicals. Several pieces of ice contacted the LH2 umbilical cavity sill and were deflected outward. No tile damage was visible. (OTV 109, 164).

A foam-colored piece of debris and a white object entered the camera field of view right side at 14:48:55.439 and 14:48:57.452 GMT, respectively, moving in a +Y direction. Both objects were unfocused and are believed to have passed close to the camera lens. No contact with either the vehicle or LH2 TSM -Z side was observed (E-18).

A part of the LH2 TSM purge barrier, with tape along the edge, came loose and was visible above the LH2 T-0 umbilical during SSME startup (E-18).

A flexible piece of debris, probably a piece of SRB sound suppression water trough, was ejected out of the LH SRB exhaust hole at T-0, appeared to contact the Orbiter lower surface, and was deflected upward a short distance before falling aft. No tile damage was visible (E-31, frame 1408; E-36, 49:00.737 GMT).

There was no discernible damage to TPS on the ET nose cone, fairing, or footprint area after the GVA was retracted (OTV 160, 162).

GUCP disconnect from the ET was nominal. Frost-covered foam, but no damage, was visible in the area after retraction. (OTV 104; E-33).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 150, 170, 171).

A stud hang-up occurred on holddown post #5. Two semi-circular pieces of aluminum from the SRB aft skirt stud hole fell downward between the aft skirt and the holddown post #5 shoe. No ordnance fragments or frangible nut pieces fell from the DCS while in the field of view. The holddown post shoe lifted approximately 2 inches (E-12, -13).

No stud hang-ups or frangible nut/ordnance debris was observed on any of the other holddown posts.

Numerous pieces of SRB throat plug material and shredded SRB sound suppression water trough material were ejected out of the SRB exhaust holes. Some of the pieces moved toward the vehicle, but no contact was observed (E-1, -15, -16, -52).

Vapor streamed aft from the Orbiter LO2 T-0 from liftoff through the roll maneuver (E-52).

Large pieces of ET/ORB umbilical purge barrier material fell aft at T+13 through T+17 seconds MET (E-52, -213).

The object falling through the E-222 field of view at T+23 seconds MET is close to the camera and not near the vehicle. Likewise, numerous birds in the area at liftoff did not appear to be close to the vehicle.

Numerous pieces of instafoam from the SRB aft skirt area fell along side the SRB plumes during ascent (E-54).

Six flares occurred in the SSME plume during ascent (E-213, -222).

Body flap movement (amplitude and frequency) appeared similar to previous flights (E-213, -220, -223).

Localized flow condensation collars at various points on the vehicle were expected for the ambient weather conditions (E-213, -220, -223, -224; OTV 4B, OTV 21).

Exhaust plume recirculation and SRB separation appeared normal. Numerous pieces of slag were visible falling from the SRB nozzles and exhaust plume after separation (OTV 13; E-208, -212).

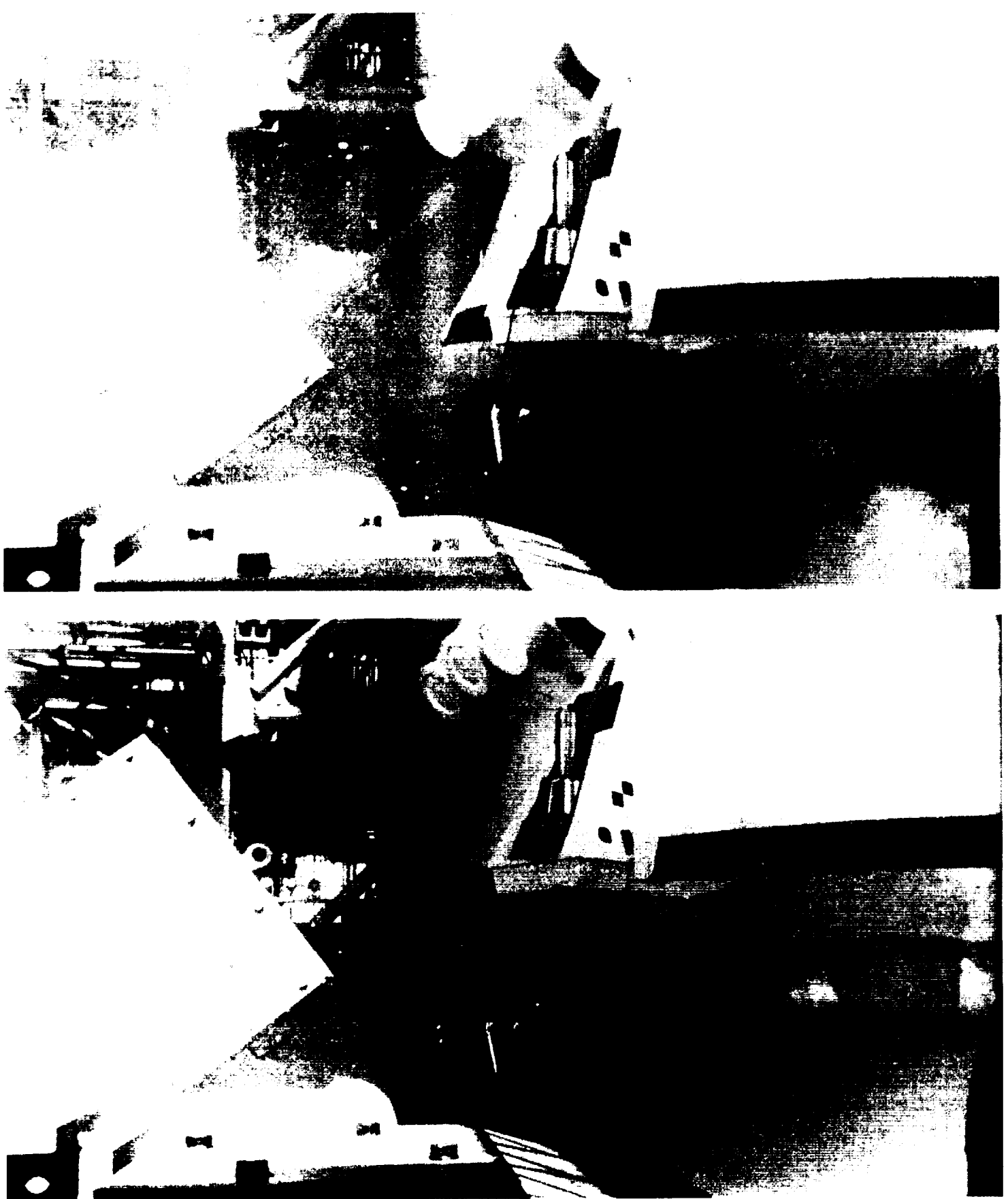


Photo 8: Holddown Post #5 Stud Hangup

A stud hang-up occurred on holddown post #5. Two semi-circular pieces of aluminum from the SRB aft skirt stud hole fell downward between the aft skirt and the HDP #5 shoe (arrow). No ordnance fragments or frangible nut pieces fell from the DCS while in the field of view.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-102 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; 35mm still views. Data was obtained from all three cameras. Handheld photography by the flight crew consisted of still images and video.

SRB separation from the External Tank was nominal.

ET-79 separation from the Orbiter was also nominal.

The new method bipod jack pad standoff closeouts were intact and undamaged.

Shallow divots, 4 to 6 inches in diameter were observed in the LH2 tank-to-intertank flange closeout: one in the +Y+Z quadrant, two in the -Y+Z quadrant, and one in the general vicinity (forward) of the -Y bipod jack pad closeout area.

The red purge barrier seal around the EO-3 fitting came loose during ET separation.

The appearance of new (uncharred) foam on both aft fairing splice plate closeouts is believed to be the result of the thin, charred surface layer of foam flaking away during ascent rather than divoting. Application of the new PDL foam in the splice plate closeouts, along with the bipod jack pad standoff closeouts, was successful.

The LH2 ET/ORB umbilical appeared to be in good condition after separation with no TPS damage. Typically, foam was eroded from the horizontal (clamshell) section of the cable tray and the aft surface of the -Y vertical strut.

The LO2 ET/ORB umbilical sustained TPS damage during separation at the forward outboard corner. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. Lightning contact strips across the forward part of the umbilical and at the 8:00 o'clock position were missing. Loss of lightning contact strips has been the subject of previous IFA's.

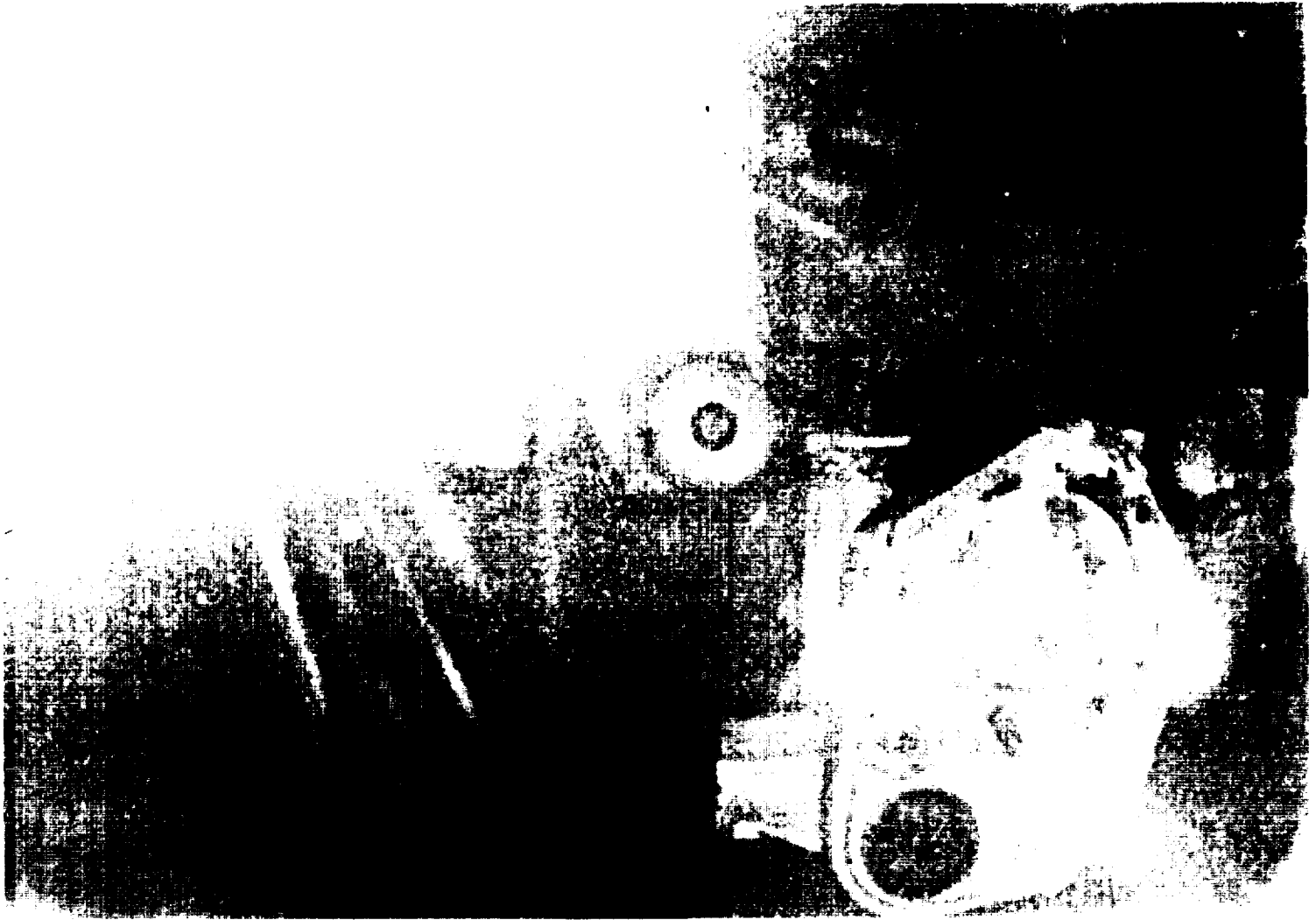


Photo 9: LH2 ET/ORB Umbilical After Separation

The LH2 ET/ORB umbilical appeared to be in good condition after separation with no TPS damage. Typically, foam was eroded from the horizontal (clamshell) section of the cable tray and the aft surface of the -Y vertical strut

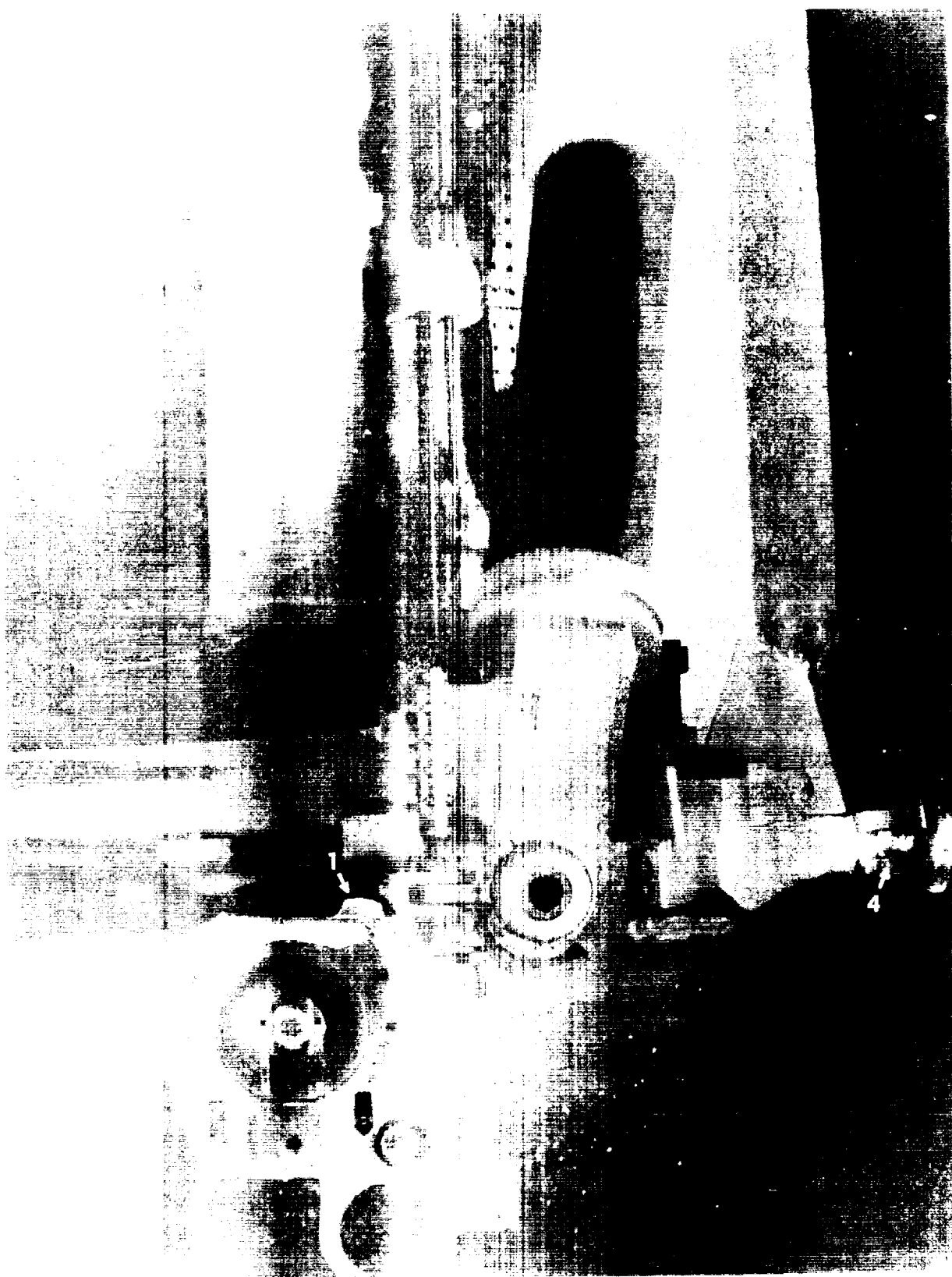


Photo 10: LO2 ET/ORB Umbilical After Separation

The LO2 ET/ORB umbilical sustained TPS damage during separation at the forward outboard corner (1). Lightning contact strips across the forward part of the umbilical and at the 8:00 o'clock position were missing (2). Loss of lightning contact strips has been the subject of previous IFA's. The red purge barrier seal around the EO-3 fitting came loose during separation (3). The appearance of new (uncharred) foam on both aft fairing splice plate closeouts is believed to be the result of the thin, charred surface layer of foam flaking away during ascent rather than divoting (4)



Photo 11: ET Intertank

The new method bipod jack pad standoff closeouts were intact and undamaged. Shallow divots, 4 to 6 inches in diameter were observed in the LH2 tank-to-intertank flange closeout: one in the +Y+Z quadrant (1), two in the -Y+Z quadrant (2), and one in the general vicinity (forward) of the -Y bipod jack pad closeout area (3).



Photo 12: ET After Separation

ET-79 separation from the Orbiter appeared nominal. No anomalies were detected in the LO2 tank, intertank, and LH2 tank acreage CPR. The BSM burn scar on the LO2 tank barrel section was typical

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 23 films and videos, which included nine 35mm large format films, two 16mm high speed films, and twelve videos, were reviewed.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. Left and right main landing gear touchdown was virtually simultaneous (right side touched down first) at approximately 2200 feet. The Orbiter drifted east of centerline during rollout then was steered back to centerline.

Drag chute deployment appeared nominal.

Touchdown of the nose landing gear was smooth.

No significant TPS damage was visible. The reddish-brown discoloration from a previous flight on the forward section of the left payload bay door appeared unchanged. Rollout and wheel stop were uneventful.

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-081 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 24 June 1996. From a debris standpoint, both SRB's were in excellent condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS. The number of debonds over fasteners (25) was less than average (Figure 1). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position.

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact though some of the phenolic layers had delaminated. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips were missing from the severance ring.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ETA ring, IEA, and IEA covers appeared undamaged. Several stiffener rings had been damaged by water impact. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Aft skirt MSA-2 was intact. More than usual amounts of foam were missing from the aft skirt aft ring. Launch films showed numerous light colored particles, believed to be pieces of foam, falling along side the SRB plumes during ascent.

The HDP #1 and #3 Debris Containment Systems (DCS) plungers were obstructed by frangible nut halves and a 2-inch long by 1-inch wide by 1/4-inch thick piece of K5NA, respectively. No anomalies on HDP #1 and #3 were observed in the launch films and the two conditions may have been caused by water impact. The HDP #2 and #4 DCS functioned properly.

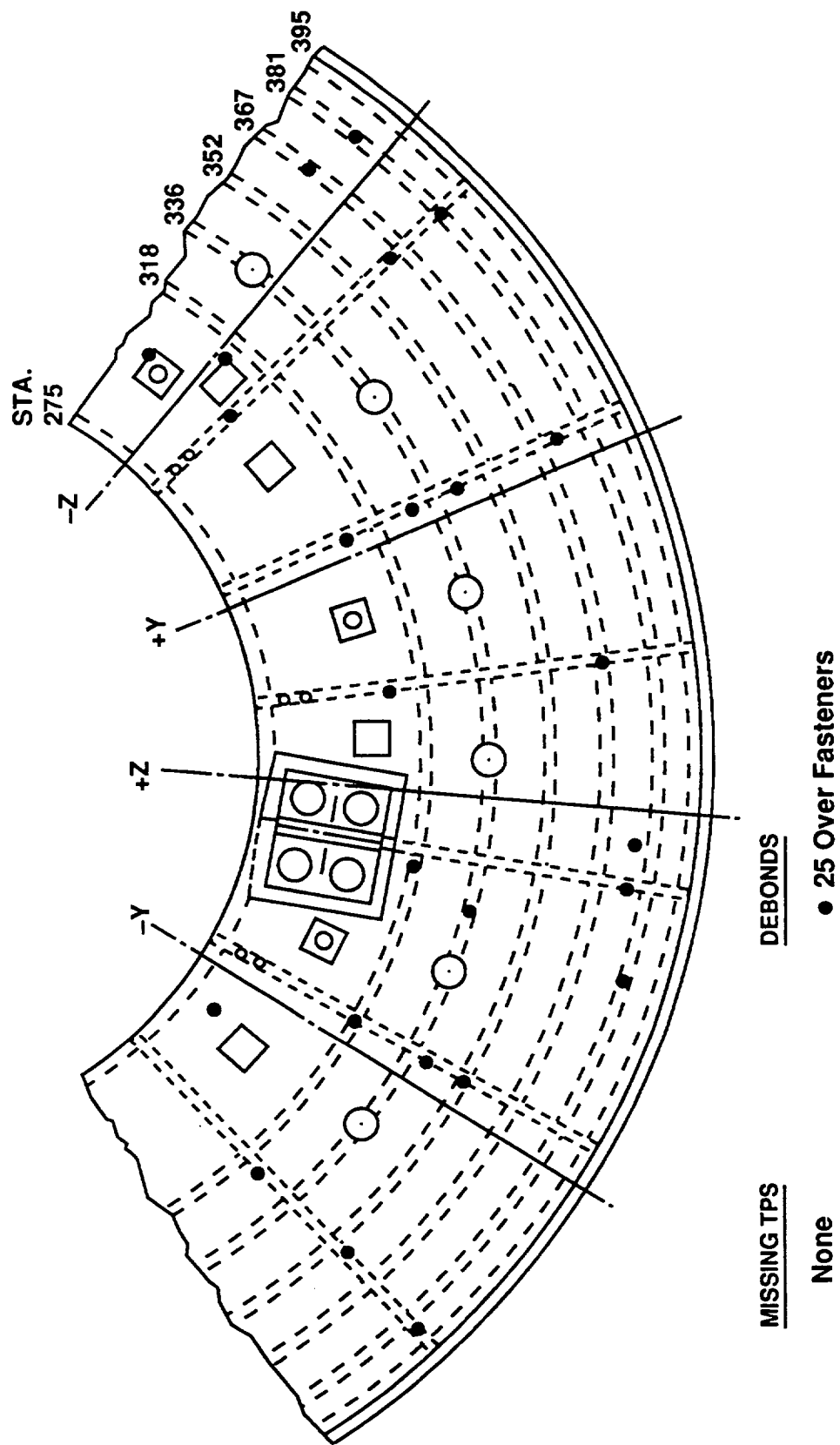


Figure 1: RH SRB Frustum

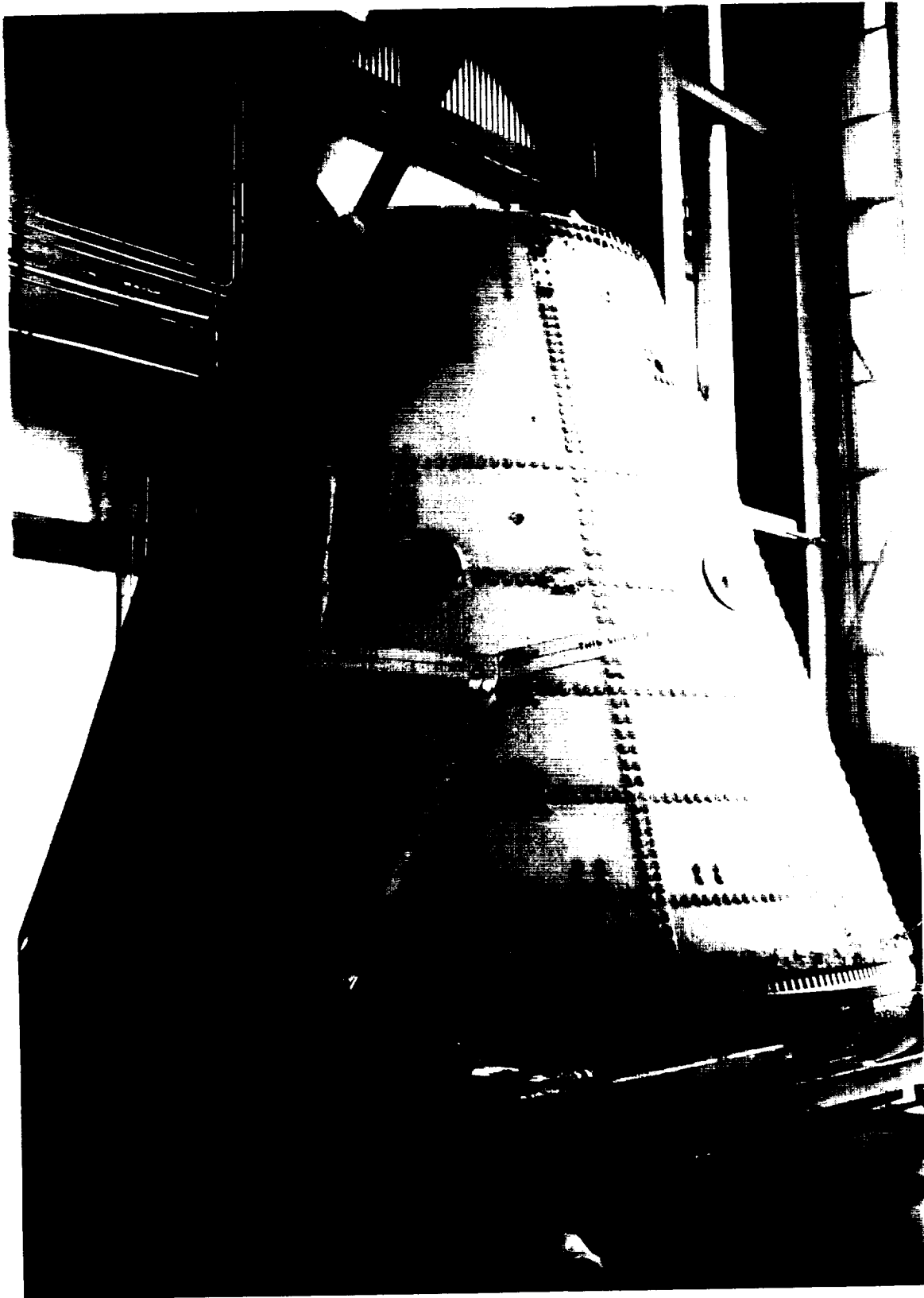


Photo 13: RH Frustum

The RH frustum was missing no TPS. The number of debonds over fasteners (25) was less than average. Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position.



Photo 14: RH Forward Skirt

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact though some of the phenolic layers were delaminated. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips were missing from the frustum severance ring.



Photo 15: Effects of Nozzle Severance

Hot or burning debris from nozzle severance prior to splashdown left charred residue and scorch marks on the SRM cases/systems tunnel closeouts



Photo 16: Aft Skirt Aft Ring Missing Foam

More than usual amounts of foam were missing from the aft skirt aft ring. Launch films showed numerous light colored particles, believed to be pieces of foam, falling along side the SRB plumes during ascent.



Photo 17: RH Aft Booster/ Aft Skirt

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS. The number of MSA-2 debonds over fasteners (42) was somewhat greater than average with a large percentage of this number consisting of partial debonds on the leading edge of the fasteners (Figure 2). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position though the two right cover attach rings had been bent by parachute entanglement.

The LH forward skirt exhibited no TPS debonds. Both RSS antennae covers/phenolic base plates were intact though some of the phenolic layers had delaminated. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips from the frustum severance ring were missing or damaged.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ETA ring, IEA, and IEA covers appeared undamaged. Several stiffener rings had been damaged by water impact. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Aft skirt MSA-2 was intact. More than usual amounts of foam were missing from the aft skirt aft ring. Launch films showed numerous light colored particles, believed to be pieces of foam, falling along side the SRB plumes during ascent.

A stud hang-up occurred on HDP #5 and the hole was broached. Stud impressions were visible in the stud hole wall. The stud hang-up was confirmed in the launch film review on film item E-12. The HDP Debris Containment System (DCS) plunger, which was seated, pinched an orange seal from the plunger assembly. The remaining DCS appeared to have functioned properly and all the plungers were seated.

SRB Post Launch Anomalies are listed in Section 9.

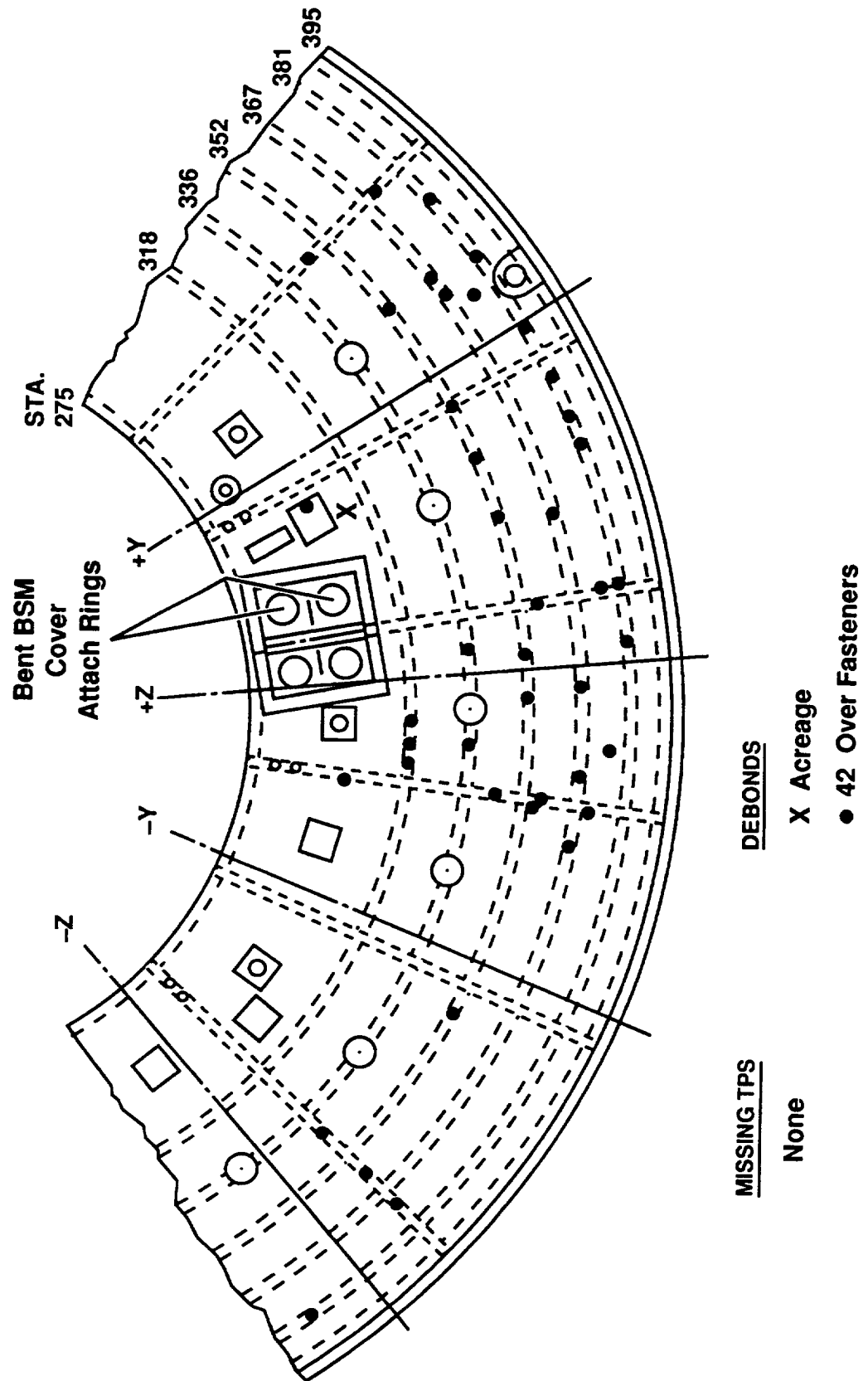


Figure 2: LH SRB Frustum



Photo 18: LH Frustum

The LH frustum was missing no TPS. The number of MSA-2 debonds over fasteners (42) was somewhat greater than average with a large percentage of this number consisting of partial debonds on the leading edge of the fasteners. The BSM aero heat shield covers had locked in the fully opened position though the two right cover attach rings had been bent by parachute entanglement.

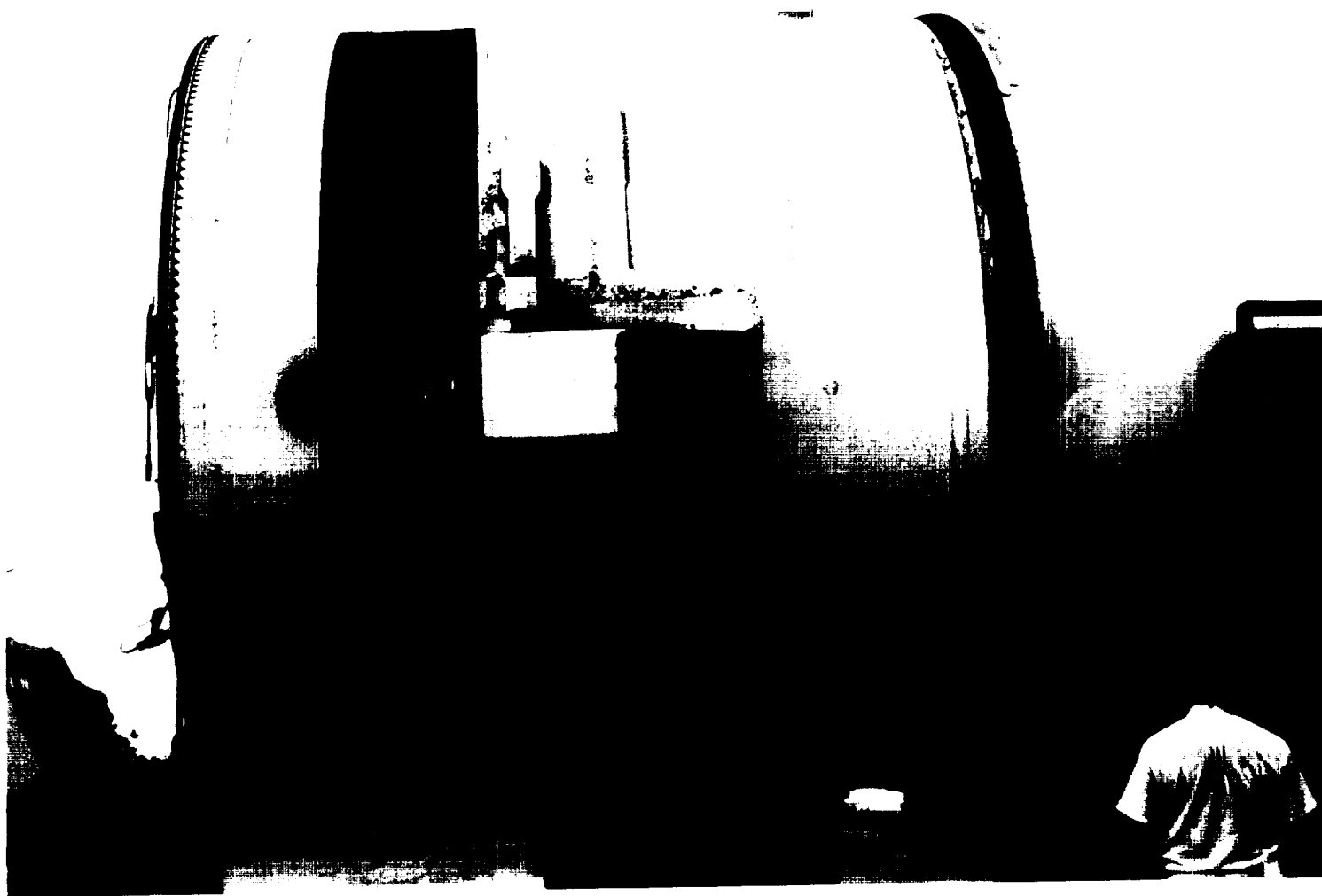


Photo 19: LH Forward Skirt

The LH forward skirt exhibited no TPS debonds. Both RSS antennae covers/phenolic base plates were intact though some of the phenolic layers had delaminated. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips from the frustum severance ring were missing or damaged.



Photo 20: LH Aft Booster/ Aft Skirt



Photo 21: HDP #5 Stud Hole Broaching

A stud hang-up occurred on HDP #5 and the stud hole was broached. Stud impressions were visible in the stud hole wall (arrow). The stud hang-up was confirmed in the launch film review. The HDP DCS plunger, which was seated, pinched an orange seal from the plunger assembly.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing inspection of OV-102 Columbia was conducted 7-9 July 1996 at the Kennedy Space Center on SLF runway 33 and in the Orbiter Processing Facility bay #1. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 85 hits, of which 12 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 62 previous missions of similar configuration (excluding missions STS-23, 24, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits and the number of hits 1-inch or larger were significantly less than average (reference attached figures).

The following table breaks down the STS-78 Orbiter debris damage by area:

	<u>HITS > 1"</u>	<u>TOTAL HITS</u>
Lower surface	5	35
Upper surface	3	34
Right side	0	2
Left side	3	4
Right OMS Pod	0	5
Left OMS Pod	1	5
TOTALS	12	85

The largest lower surface tile damage site was located aft of the ET/ORB umbilicals and measured 2.5-inches long by 0.5-inches wide by 0.5-inch maximum depth. The damage was most likely caused by an ice impact from the umbilicals.

Tile damage sites aft of the LH2 and LO2 ET/ORB umbilicals, usually caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream, were less than usual in number and size.

No tile damage from micrometeorites or on-orbit debris was identified during this inspection.

The tires and brakes were reported to be in average condition for a landing on the KSC concrete runway. Ply undercutting occurred on the left MLG inboard tire.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. Two clips were missing from the EO-2 'salad bowl' fitting. No ordnance fragments were found on the runway beneath the umbilical cavities. However, several pieces of purge barrier material held together with mylar tape lay on the runway beneath the LH2 ET/ORB umbilical. Debris, which appeared to be a small piece of lockwire adhering to a piece of mylar tape, was wedged between the forward 16mm camera lens and window. The field of view for both SRB and ET separation may have been obstructed. Virtually no umbilical closeout foam or white RTV dam material adhered to the umbilical plate near the LH2 recirculation line disconnect.

The SSME #1 Dome Mounted Heat Shield (DMHS) closeout blankets were torn and frayed at the 7:00 o'clock position. Significant tearing and fraying to the SSME #3 DMHS blankets occurred from 7:00 to 12:00 o'clock. Although the face panels were still attached, some of the underlying batting material may be missing. The SSME #2 DMHS blankets were undamaged.

Tiles on the vertical stabilizer "stinger" were intact and undamaged. However, one tile at the +Y-Z corner of the drag chute cavity was chipped.

Damage to approximately half of one tile on the trailing edge of the left rudder/speed brake did not appear related to drag chute deployment. A previous repair to that tile most likely shook loose during SSME ignition and ascent.

No ice adhered to the payload bay door. The reddish-brown discoloration on the leading edge of the LH payload bay door had not changed in appearance. No unusual tile damage was observed on the leading edges of the vertical stabilizer and OMS pods.

A somewhat unusual finding was a tile damage site on the upper surface of the left wing near the leading edge but aft of the RCC panels. The damage site measured approximately 5-inches long by 0.75-inches wide by 0.125-inches deep and was oriented in the longitudinal (-X) direction.

Hazing and streaking of Orbiter windows #2, #3, and #4 was typical. Damage sites on the window perimeter tiles (five hits on window #2; five hits on #3; and four hits on #4) were determined to be new hits. Numerous other damage sites were attributed to old repair material flaking off. A tile between windows #3 and #4 exhibited a damage site 2-inches long by 1-inch wide by 0.125-inches deep.

The post landing walkdown of Runway 33 was performed immediately after landing. No debris concerns were identified. All drag chute hardware was recovered and appeared to have functioned normally.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger were significantly less than average when compared to previous missions.

Post Landing Anomalies are listed in Section 9.0.

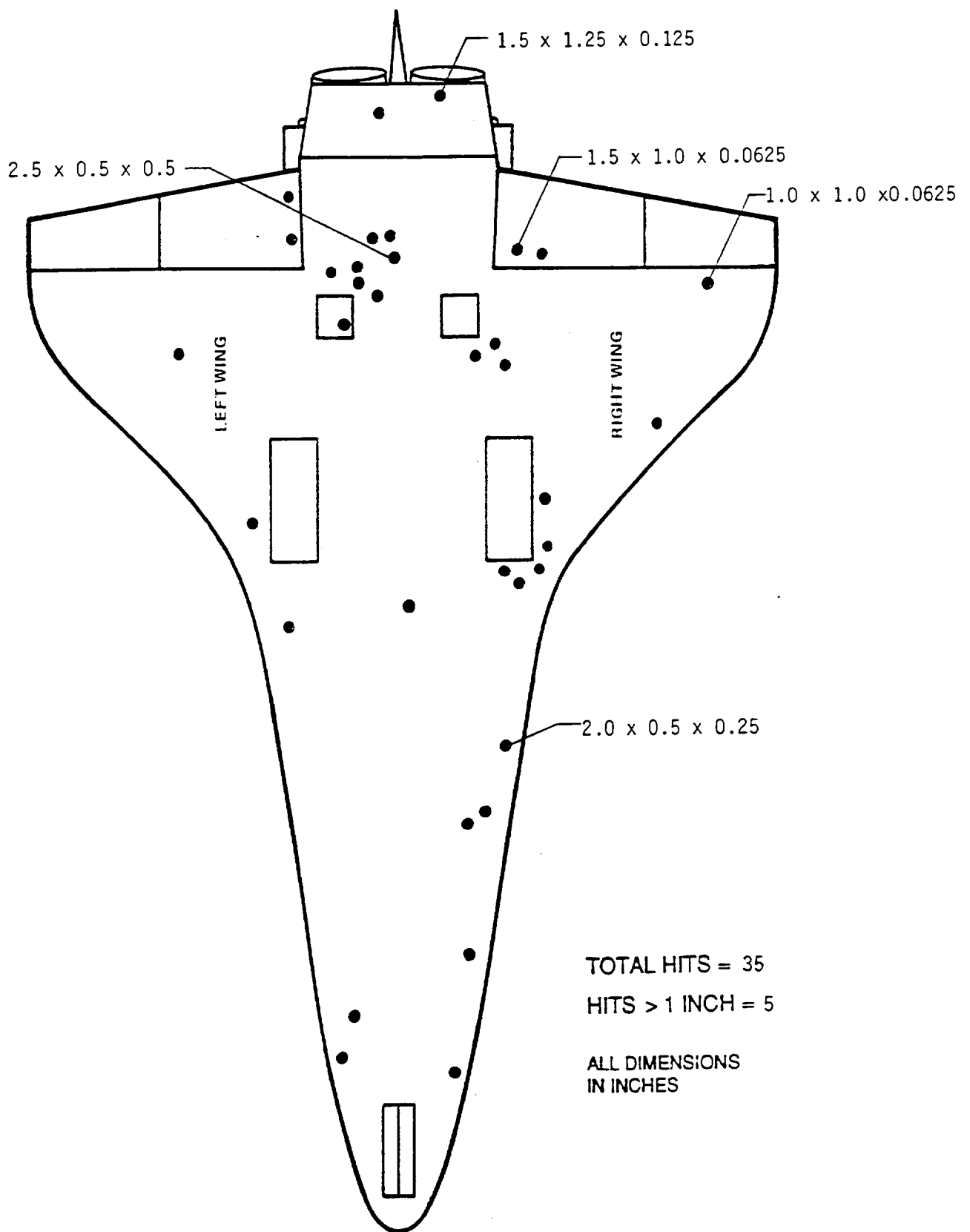


Figure 3: Orbiter Lower Surface Debris Map

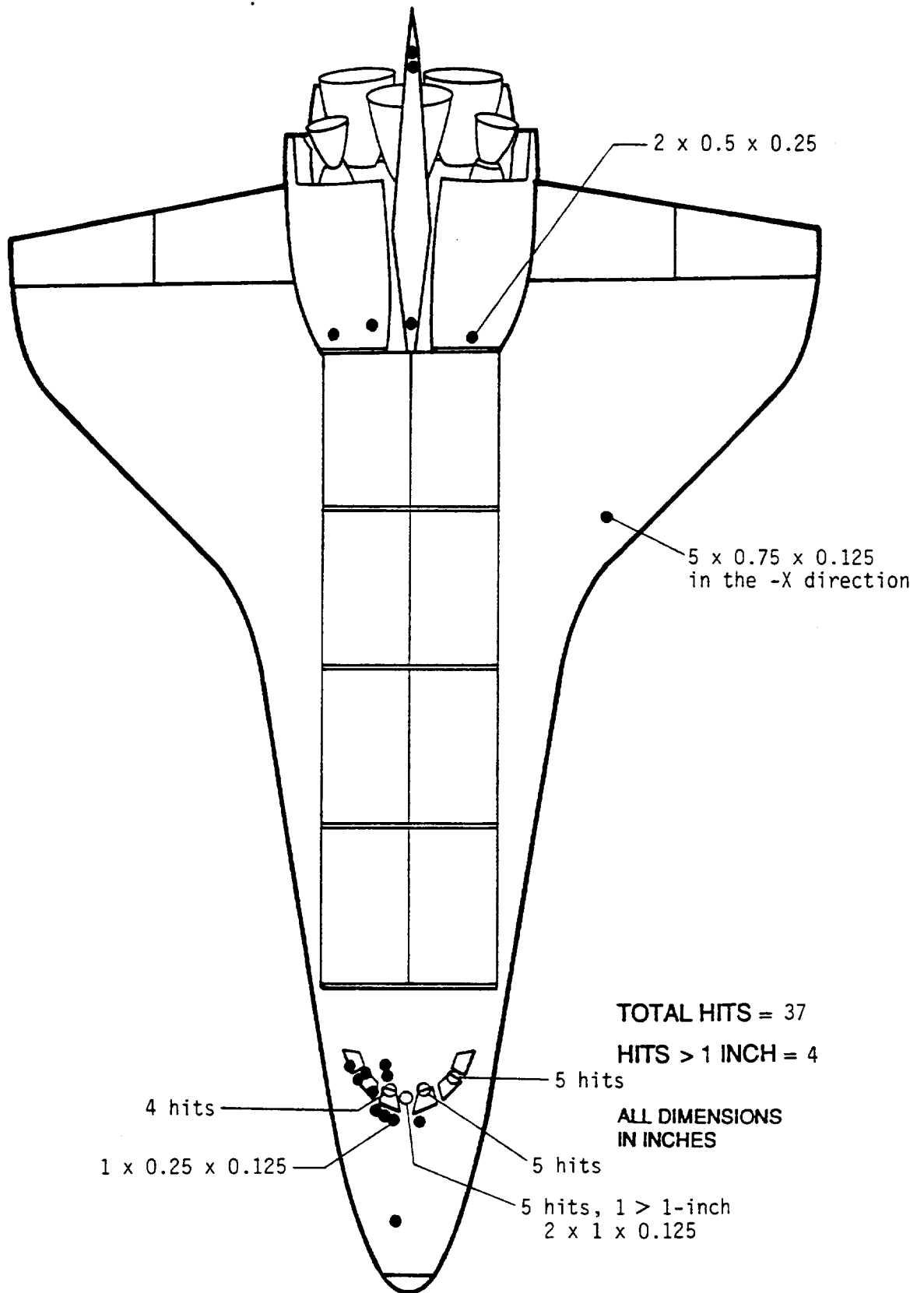
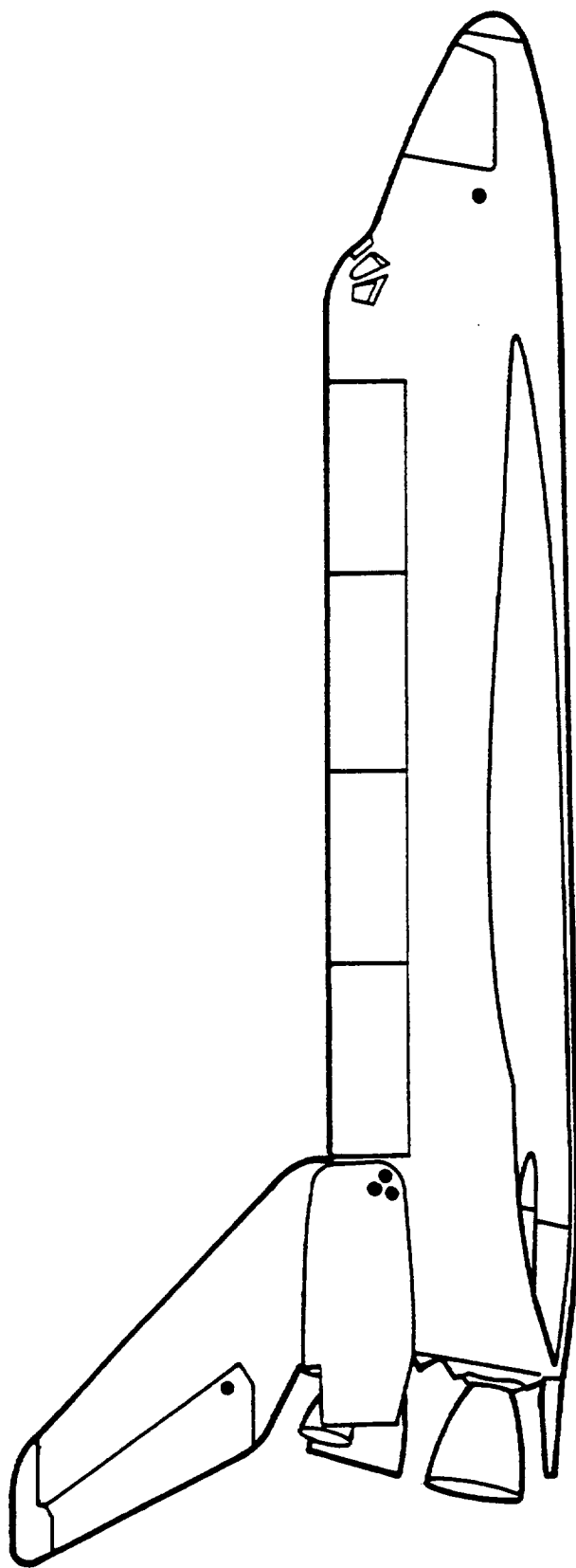


Figure 4: Orbiter Upper Surface Debris Map



TOTAL HITS = 5
HITS > 1 INCH = 0

Figure 5: Orbiter Right Side Debris Map

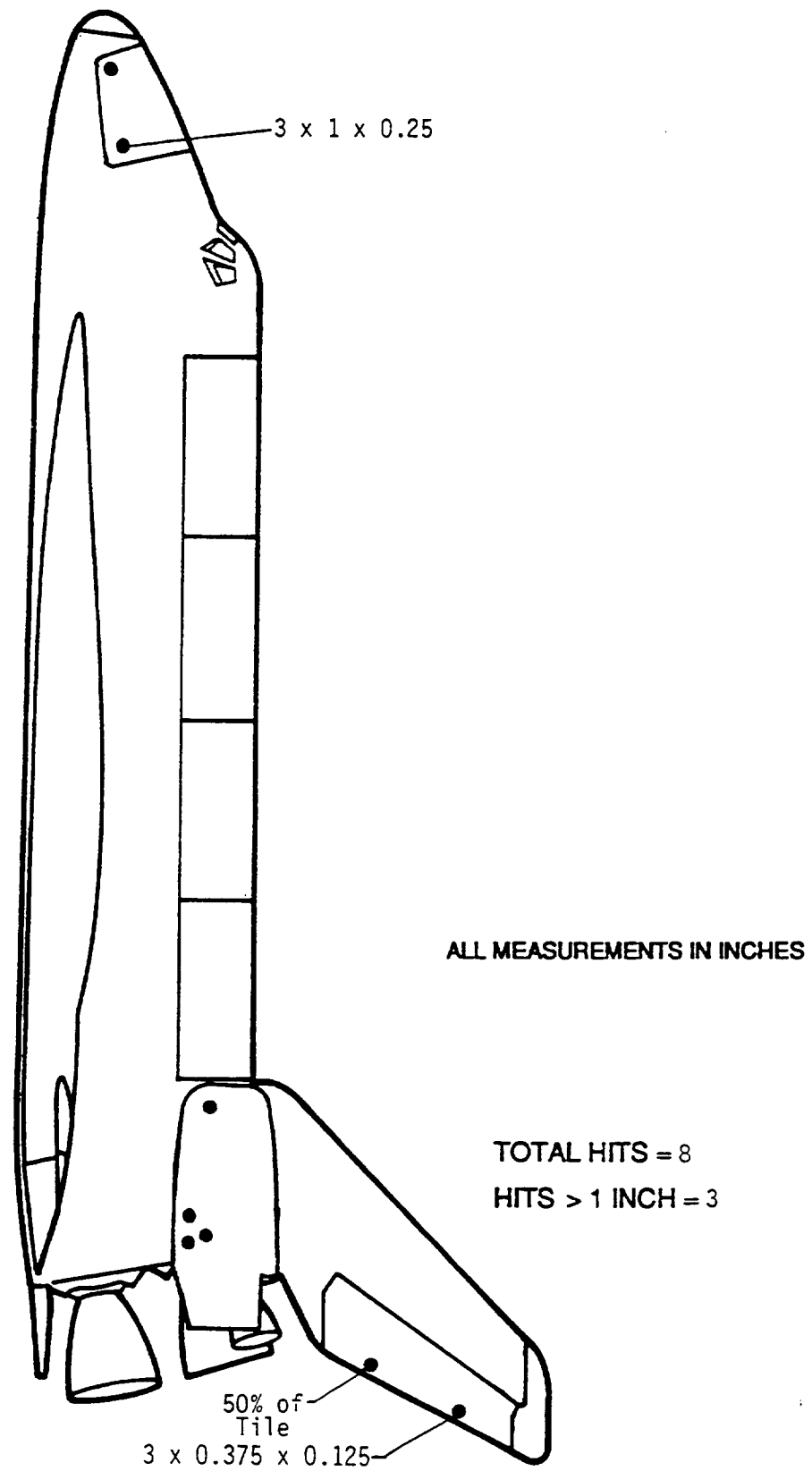


Figure 6: Orbiter Left Side Debris Map

	LOWER SURFACE			ENTIRE VEHICLE				LOWER SURFACE			ENTIRE VEHICLE		
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH		HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	HITS > 1 INCH	TOTAL HITS	TOTAL HITS
STS-6	21	89	36	7	56	120	STS-51	8	100	18	154		
STS-8	3	29	7	14	58		STS-58	23	78	26	155		
STS-9 (41-A)	9	49	14	34	63		STS-61	7	59	13	120		
STS-11 (41-B)	11	19	34	8	36		STS-60	4	48	15	106		
STS-13 (41-C)	5	27	8	30	111		STS-62	7	36	16	97		
STS-14 (41-D)	10	44	30	36	154		STS-59	10	47	19	77		
STS-17 (41-G)	25	69	36	20	87		STS-65	17	123	21	151		
STS-19 (51-A)	14	66	20	28	81		STS-64	18	116	19	150		
STS-20 (51-C)	24	67	33	33	141		STS-68	9	59	15	110		
STS-27 (51-I)	21	96	17	17	111		STS-66	22	111	28	148		
STS-28 (51-J)	7	66	34	55	183		STS-63	7	84	14	125		
STS-30 (61-A)	24	129	55	39	257		STS-67	11	47	13	76		
STS-31 (61-B)	37	177	39	23	132		STS-71	24	149	25	164		
STS-32 (61-C)	20	134	20	18	53		STS-70	5	81	9	127		
STS-29	18	60	20	20	76		STS-69	22	175	27	198		
STS-28R	13	51	18	21	118		STS-73	17	102	26	147		
STS-34	17	107	15	15	120		STS-74	17	78	21	116		
STS-33R	21	111	19	19	81		STS-72	3	23	6	55		
STS-32R	13	61	14	16	63		STS-75	11	55	17	96		
STS-36	17	47	16	12	106		STS-76	5	32	15	69		
STS-31R	13	64	8	17	81		STS-77	15	48	17	81		
STS-41	13	70	17	10	113		AVERAGE	13.9	88.7	20.6	128.4		
STS-38	7	132	10	16	238		SIGMA	7.2	43.8	9.6	53.8		
STS-35	15	91	25	25	197		STS-78	5	35	12	85		
STS-37	7	217	16	25	131								
STS-39	14	153	25	25	182								
STS-40	23	122	9	22	101								
STS-43	24	100	22	11	114								
STS-48	14	74	11	45	184								
STS-44	6	122	22	22	236								
STS-45	18	55	11	11	108								
STS-49	6	141	22	16	290								
STS-50	28	186	11	23	240								
STS-46	11	48	11	14	131								
STS-47	3	152	16	36	156								
STS-52	6	145	13	13	143								
STS-53	11	80	10	10	75								
STS-54	14	94	12	12									
STS-56	18	128	10	10									
STS-55	10	75	10	10									
STS-57	10		10	10									

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS
SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 7: Orbiter Post Flight Debris Damage Summary

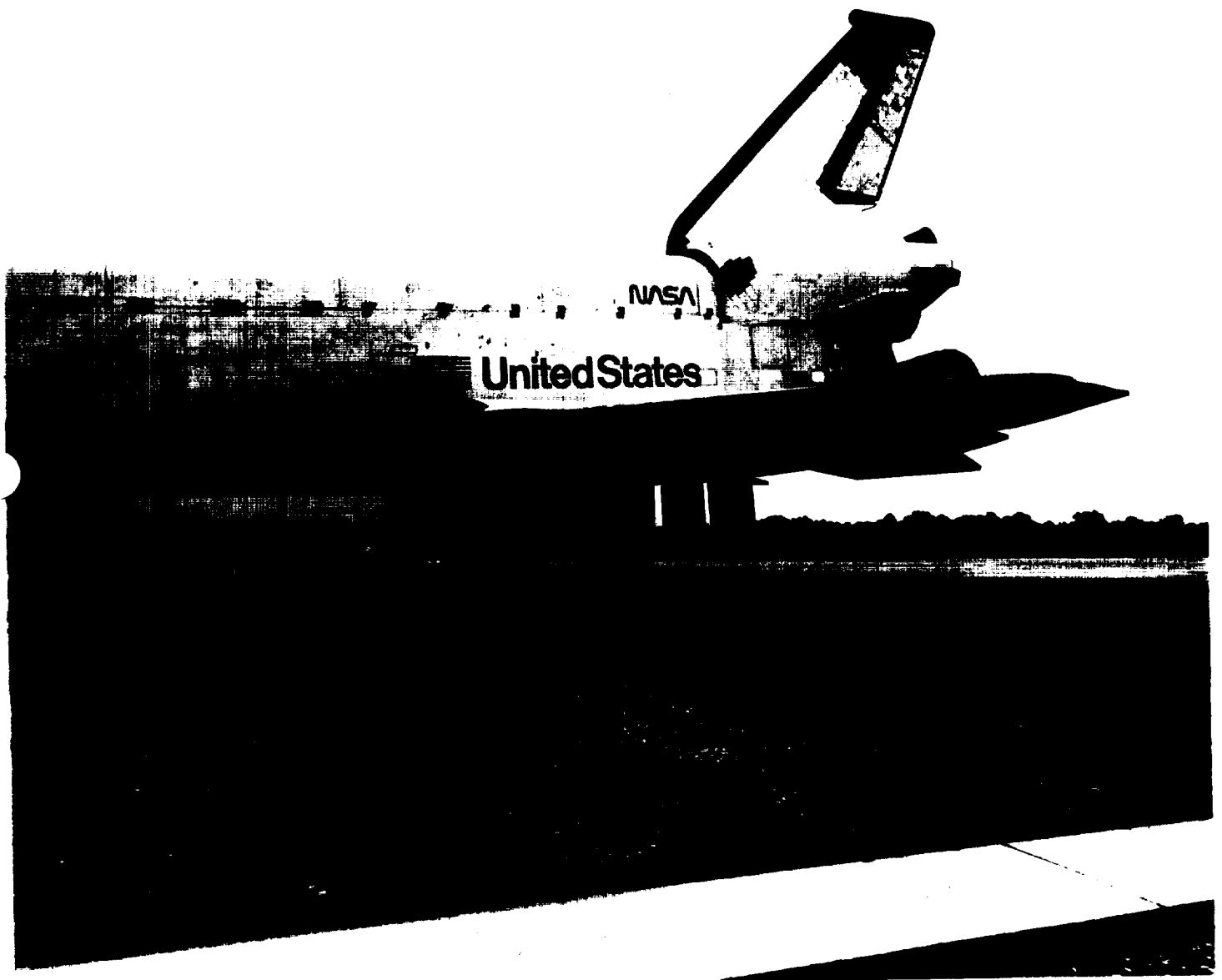


Photo 22: Orbiter Left Side Midbody and Aft Fuselage

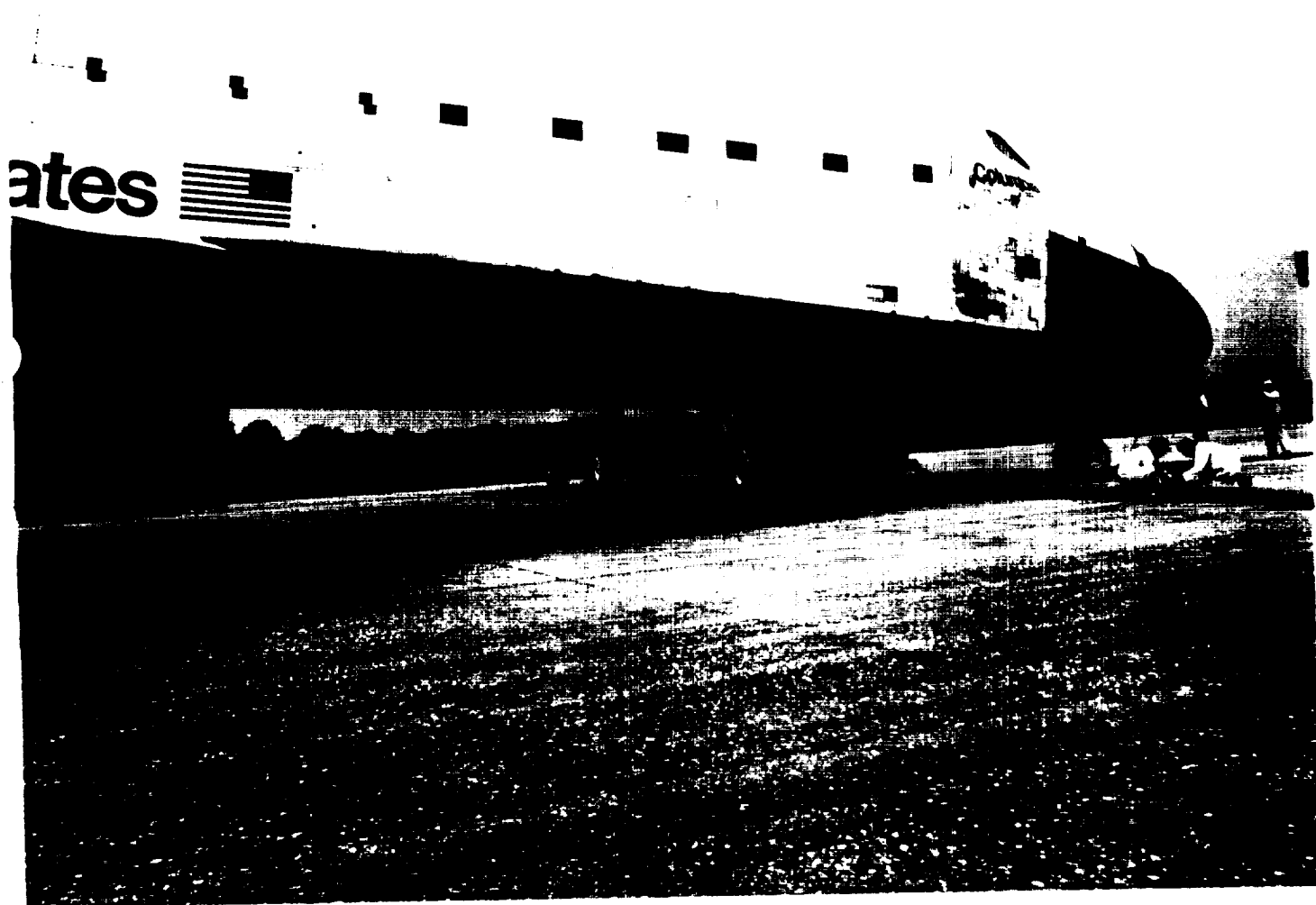


Photo 23: Orbiter Right Side Midbody and Nose



Photo 24: Base Heat Shield/SSME's



Photo 25: SSME #3 DMHS Closeout Blankets

Significant tearing and fraying to the SSME #3 DMHS closeout blankets occurred from the 7:00 to 12:00 o'clock locations. Although the face panels were still attached, some of the underlying batting material may be missing.

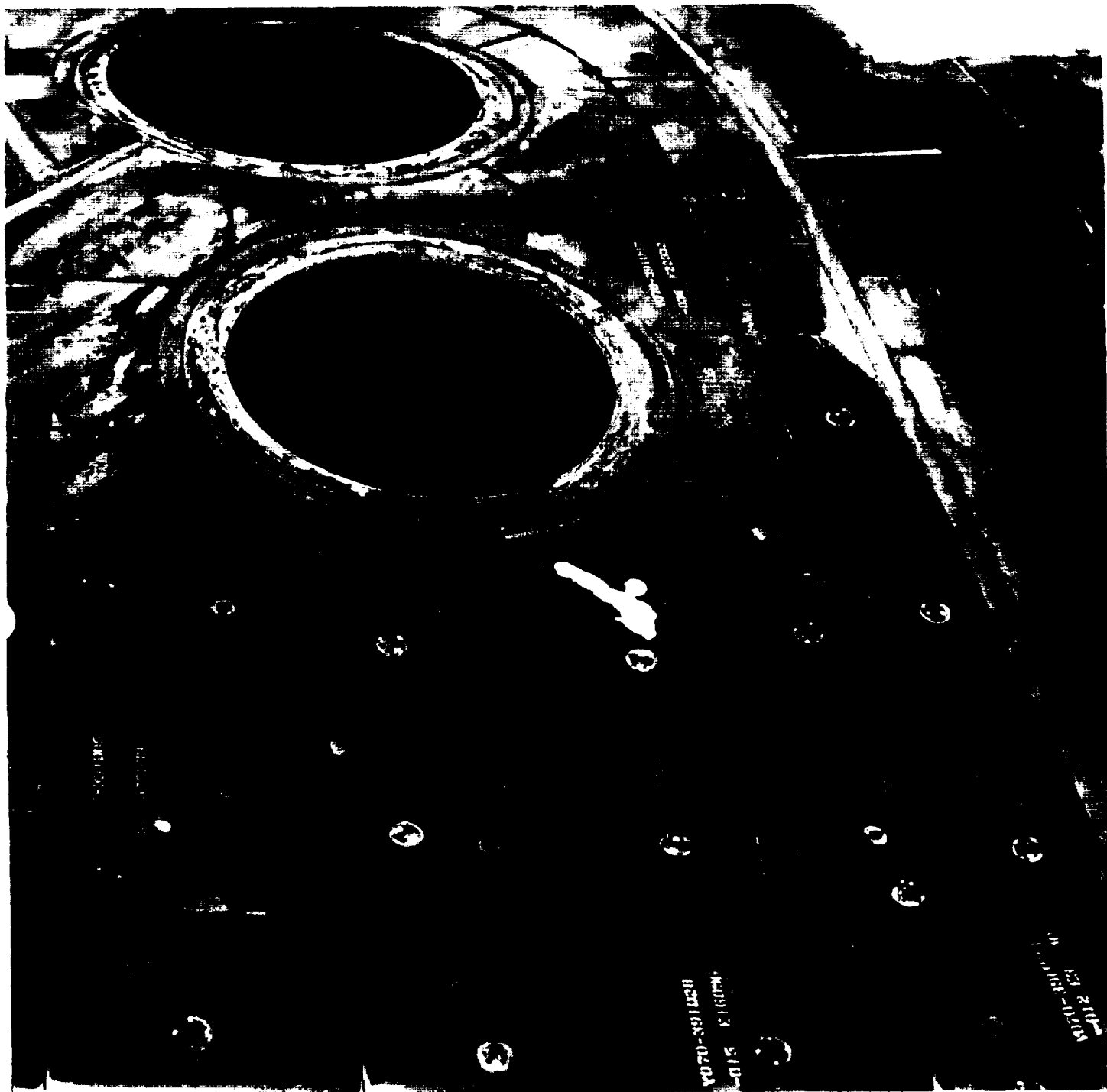


Photo 26: FRCS Tile Damage

Tile damage site measuring 3 x 1 x 0.25 inches was located near the F3L thruster



Photo 27: LH2 ET/ORB Umbilical

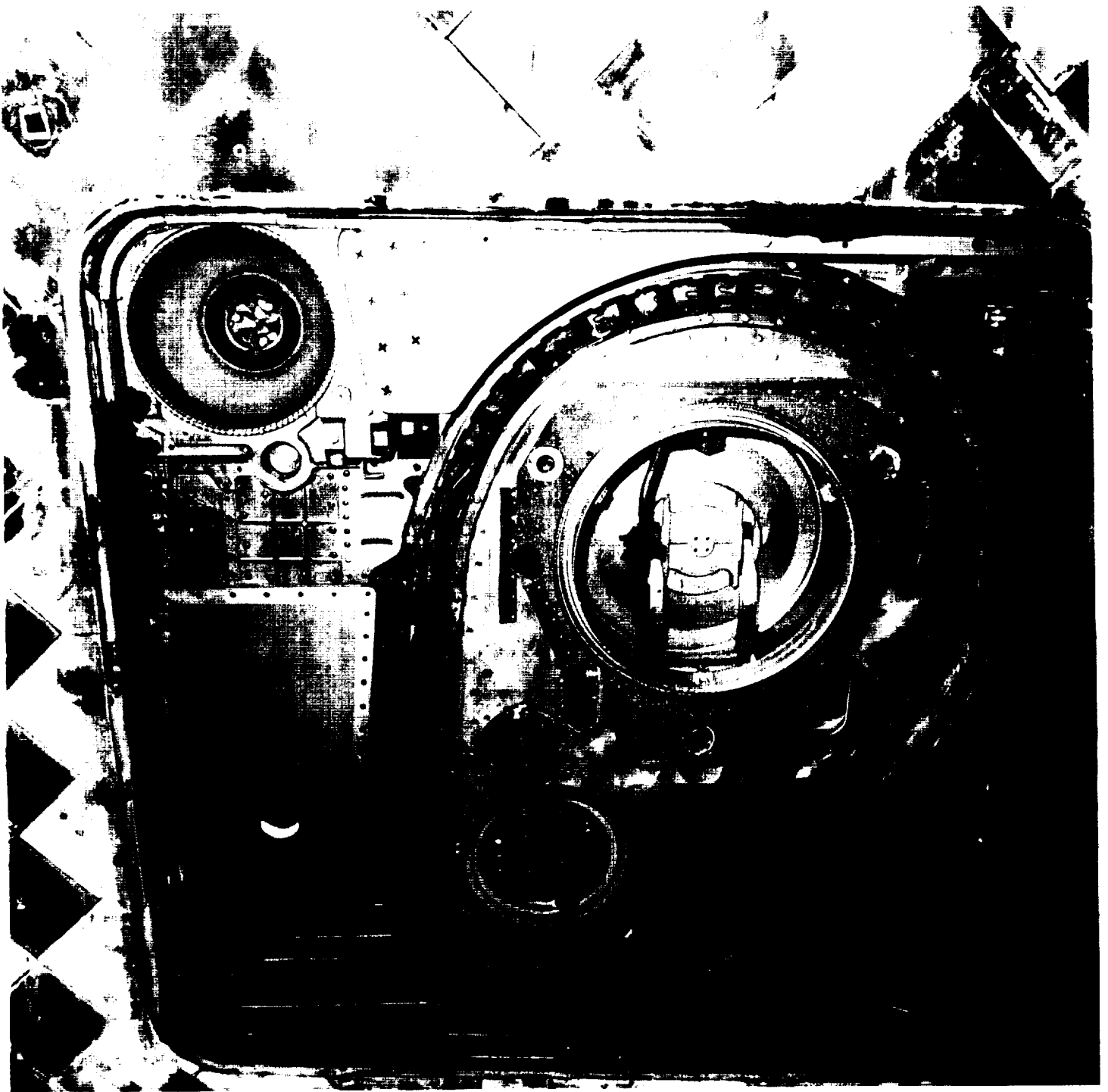


Photo 28: LO2 ET/ORB Umbilical

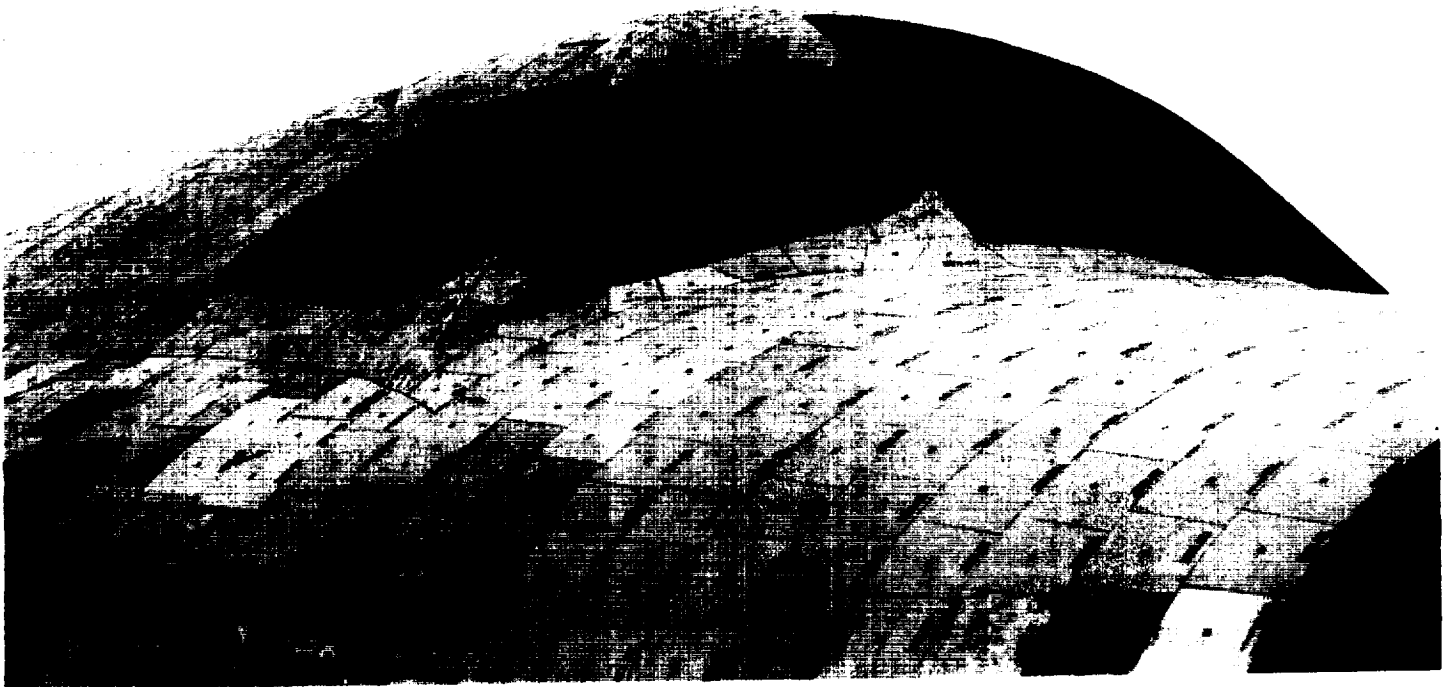
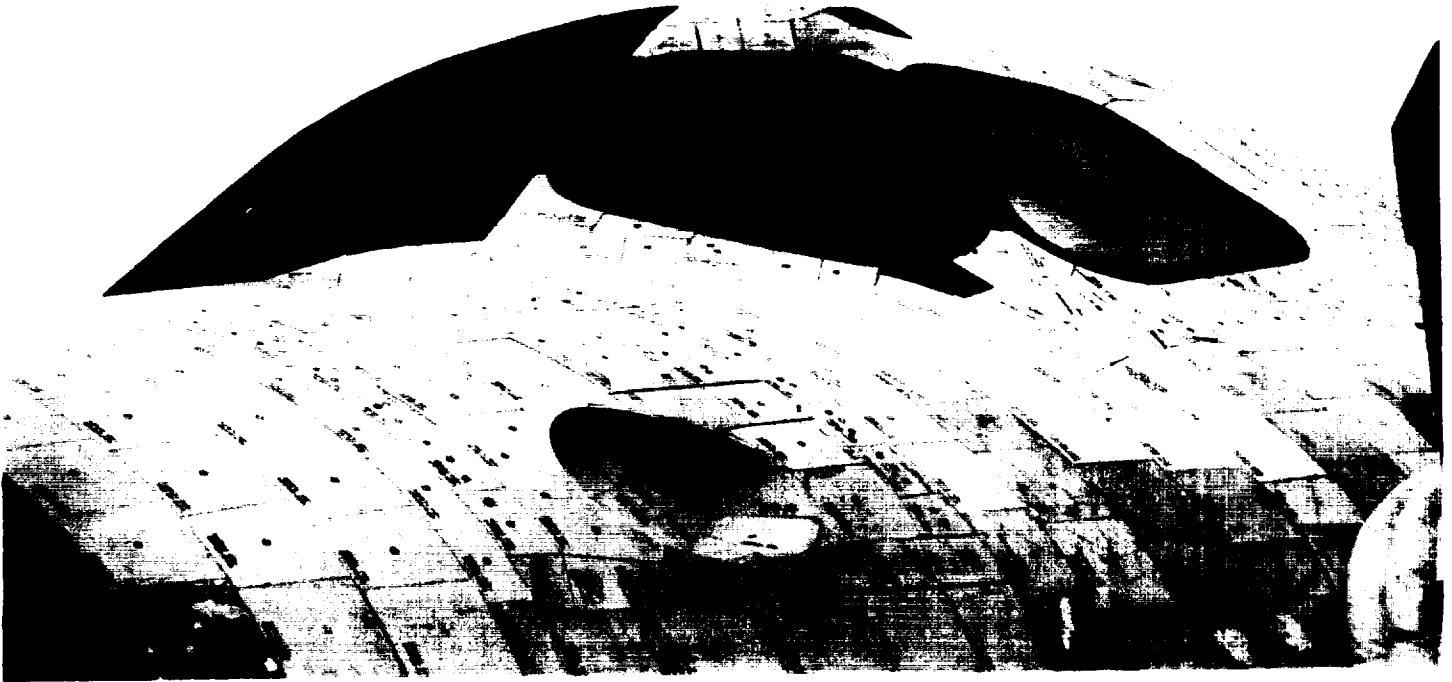


Photo 29: Orbiter Windows

Hazing and streaking of Orbiter windows #2, #3, and #4 was typical. Damage sites on the window perimeter tiles (five hits on window #2; five hits on #3; and four hits on #4) were determined to be new hits. Numerous other damage sites were attributed to old repair material flaking off. A tile between windows #3 and #4 exhibited a damage site 2 x 1 x 0.125-inches deep.



Photo 30: Damaged Tile on Rudder/Speed Brake

Damage to approximately half of one tile on the trailing edge of the left rudder/speed brake did not appear related to drag chute deployment. A previous repair to that tile most likely shook loose during SSME ignition and ascent

8.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-102 Columbia during the STS-78 post landing debris assessment at Kennedy Space Center. The submitted samples consisted of 8 wipes from Orbiter windows #1-8. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries.

8.1 ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to facility environment, SRB BSM exhaust (including metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (tile repair, and glass insulation), Orbiter window polish residue, and building type insulation. There was no apparent vehicle damage related to these residuals.

8.2 ORGANIC ANALYSIS

The results of the STS-78 organic analysis are pending.

8.3 STS-76 ORGANIC ANALYSIS

The results of the recently-received STS-76 organic sample analysis revealed the presence of vinyl, insect debris and epoxy materials. These particulate types are common to STS processing. The precise sources are under assessment.

8.4 STS-77 ORGANIC ANALYSIS

The results of the recently-received STS-77 organic sample analysis revealed the presence of RTV (RCS nozzle cover and ORB TPS), filled rubber and paints. These particulate types are common to STS processing, the precise sources are under assessment.

8.5 NEW FINDINGS

Vinyl material as noted in STS-76 organic analysis is a new finding, precise source is under investigation. These material types are common to the STS environment. The variety of residual material continues to be representative of that documented in previous mission sampling (reference Figure 8 for STS-78).

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
78	Metallics - Fac Env /BSM Residue(SRB) Tile, Tile repair (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Earth Minerals Organics Window polish residue				
77	Metallics - Fac Env /BSM Residue(SRB) Tile, Tile repair (ORB TPS) Insulation Glass(ORB TPS) Building type insulation Earth Minerals Organics - RTV,plastic polymers,rubber Paints and primer				
76	Metallics - Fac Env /BSM Residue(SRB) Tile repair (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Earth Minerals Organics - Insect debris,vinyl,plastic polymers Window polish residue Paint and primer Carbon black/copper alloy				
75	Metallics - Fac Env /BSM Residue(SRB) Tile repair (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Earth Minerals Organics - Plastics, cellulosic Window polish residue Paint and primer				
72	Metallics - Fac Env /BSM Residue(SRB) RTV Tile, Tile repair (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Earth Minerals Organics - Plastics, cellulosic Window polish residue Paint and primer				Pre-launch Window Cover Metallic-Fac Env ,RTV Tile-(TPS) Insulation Glass - (ORB TPS) Earth Minerals, Organics--phenolic, urethane ,isocyanurate foam Pre-launch Window Metallic - Fac Env ,Window polish res RTV Tile, Tile repair,Ins glass (TPS), Earth Minerals,Paint/primer,Organics-- phenolic,urethane ,isocyanurate foam

Figure 8: Orbiter Post Landing Microchemical Sample Results

9.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 9 post launch anomalies, but no In-Flight Anomalies (IFA's), were observed on the STS-78 mission.

9.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. A foam-colored piece of debris and a white object entered the E-18 camera field of view right side at 14:48:55.439 and 14:48:57.452 GMT, respectively, moving in a +Y direction. Both objects were unfocused and are believed to have passed close to the camera lens. No contact with either the vehicle or LH2 TSM -Z side was observed.

9.2 SOLID ROCKET BOOSTERS

1. The LH frustum was missing no TPS. The number of MSA-2 debonds over fasteners (42) was somewhat greater than average with a large percentage of this number consisting of partial debonds on the leading edge of the fasteners.

2. More than usual amounts of foam were missing from the aft skirt aft ring. Launch films showed numerous light colored particles, believed to be pieces of foam, falling along side the SRB plumes during ascent.

3. A stud hang-up occurred on HDP #5 and the hole was broached. Stud impressions were visible in the stud hole wall. The stud hang-up was confirmed in the launch film review on film item E-12. The HDP Debris Containment System (DCS) plunger had pinched an orange seal from the plunger assembly.

9.3 EXTERNAL TANK

1. Shallow divots, 4 to 6 inches in diameter were observed in the LH2 tank-to-intertank flange closeout: one in the +Y+Z quadrant, two in the -Y+Z quadrant, and one in the general vicinity (forward) of the -Y bipod jack pad closeout area.

2. The red purge barrier seal around the EO-3 fitting came loose during ET separation.

3. The LO2 ET/ORB umbilical sustained TPS damage during ET separation at the forward outboard corner. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. Lightning contact strips across the forward part of the umbilical and at the 8:00 o'clock position were missing. Loss of lightning contact strips has been the subject of previous IFA's.

9.4 ORBITER

1. Debris, which appeared to be a small piece of lockwire adhering to a piece of mylar tape, was wedged between the forward 16mm camera lens and window in the LH2 ET/ORB umbilical. The field of view for both SRB and ET separation may have been obstructed.

2. A somewhat unusual finding was a tile damage site on the upper surface of the left wing near the leading edge but aft of the RCC panels. The damage site measured approximately 5-inches long by 0.75-inches wide by 0.125-inches deep and was oriented in the longitudinal (-X) direction.

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

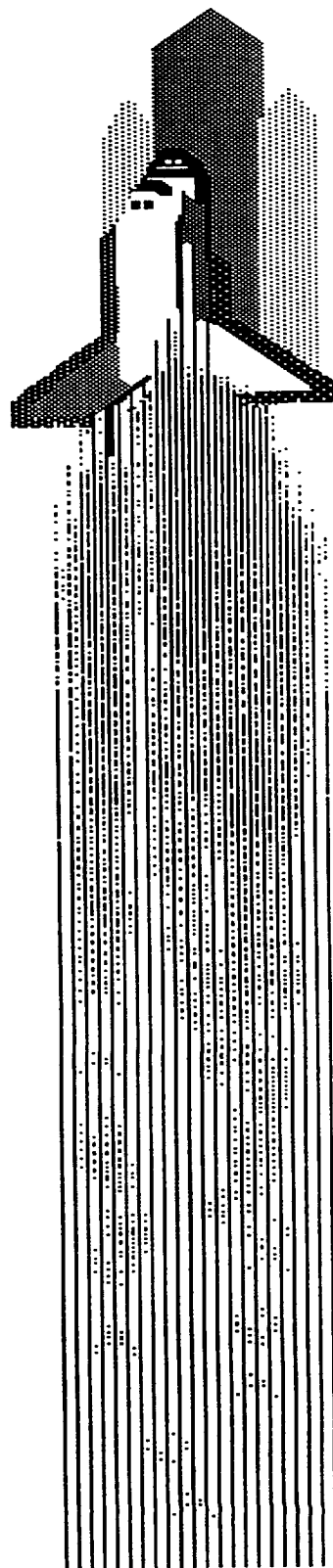
Space Shuttle

Earth Science Branch

Image Science and
Analysis Group

STS-78 Summary of Significant Events

August 7, 1996



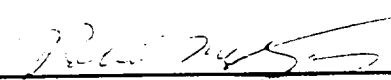
Space Shuttle Image Science and Analysis Group


STS-78 Summary of Significant Events

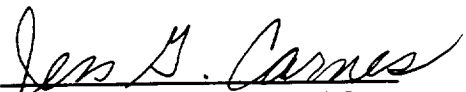
Project Work Order - SN-5CR

Approved By


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Jess G. Carnes, Operations Manager
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Prepared By

Lockheed Martin Engineering and Sciences Company
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Earth Science Branch
Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

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1. STS-78 (OV-102): Film/Video Screening and Timing Summary

1. STS-78 (OV-102): FILM / VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

The STS-78 launch of Columbia (OV-102) from pad B occurred on Thursday, June 20, 1996, (day 172) 14:49:00.028 Coordinated Universal Time (UTC) as seen on camera E9. Solid Rocket Booster (SRB) separation occurred at 14:51:03.684 UTC as seen on camera KTV4B.

On launch day, 24 of 24 expected videos were received and screened. Following launch day, 40 films were screened. Camera films E60, E76, and E212 were not received. No potential anomalies were observed during launch.

Video of the Orbiter flight-deck taken during ascent from a camera mounted near the commander's chair were down-linked by the crew. Vapors, probably from a purge, were visible through Orbiter window W1.

Detailed Test Objective 312, photography of SRB separation and the external tank (ET) after separation, was performed using the Orbiter umbilical well cameras (method 1). Handheld photography of the ET was acquired using the Nikon F4 with the 300 mm lens and 2x converter (method 3).

1.1.2 Landing

Columbia landed on runway 33 at the KSC Shuttle Landing Facility on July 7, 1996. Twelve of twelve expected videos were received. A video from the pilot's window of the landing was also received. Eleven films of the Orbiter's approach and landing were received.

No major anomalies were noted in the approach, landing, or roll-out video views screened. The drag chute deployment appeared normal.

1.2 TIMING ACTIVITIES

Launch:

The time codes from videos and films were used to identify specific events during the initial screening process.

Video cameras: ET204, ET207, ET208, ET212, ET213, KTV2, KTV4B, KTV5, KTV7B, KTV11B, KTV13, KTV21B, OTV109, OTV141, OTV148, OTV149, OTV150, OTV151, OTV154, OTV160, OTV161, OTV163, OTV170, and OTV171 had IRIG timing.

Film cameras: E31, E41, E205, E207, E208, E213, E220, and E223 had IRIG timing. E1, E2, E3, E4, E5, E7, E8, E9, E10, E11, E12, E13, E14, E15, E16, E17, E18, E19, E20, E33, E34, E36, E40, E52, E54, E57, E59, E62, E63, E77, E222, and E224 had in-frame alphanumeric timing.

1. **STS-78 (OV-102): Film/Video Screening and Timing Summary**

Landing:

Video cameras: Eleven of the twelve expected videos screened on landing day (EL17IR, EL18IR, KTV5L, KTV6L, KTV11L, KTV12L, KTV13L, KTV15L, KTV20L, KTV33L, and SLF South) had IRIG timing. SLF North did not have IRIG timing.

Film cameras: The eleven film cameras of landing (EL1, EL2, EL4, EL7, EL8, EL9, EL10, EL12, EL15, EL30, and EL31) had in-frame alphanumeric timing.

The landing and drag chute event times are provided in Table 1.2.

Event Description	Time (UTC)	Camera
Landing Gear - Doors Opened	189:12:36:14.622	KTV33L
Right Main Wheel Touchdown	189:12:36:33.945	EL18IR
Left Main Wheel Touchdown	189:12:36:34.212	EL18IR
Drag Chute Initiation	189:12:36:39.709	KTV11L
Pilot Chute at Full Inflation	189:12:36:40.609	KTV6L
Bag Release	189:12:36:41.210	KTV11L
Drag Chute Inflation in Reefed Configuration	189:12:36:42.145	KTV11L
Drag Chute Inflation in Disreefed Configuration	189:12:36:45.615	KTV11L
Nose Wheel Touchdown	189:12:36:47.008	KTV11L
Drag Chute Release	189:12:37:11.599	KTV15L
Wheel Stop	189:12:37:31.985	KTV15L

Table 1.2 Landing Video Timing Events

2. Summary of Significant Events

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS

2.1.1 Debris Near the Time of SSME Ignition

As on previous missions, multiple pieces of debris were seen near the time of SSME ignition. Most of the debris was umbilical ice and RCS paper. No follow-up action was requested.

2.1.1.1 Object Contacts Vertical Stabilizer (Cameras: OTV171 and E77)



Figure 2.1.1.1 Object Contacts Vertical Stabilizer

A light colored object, first seen between SSME #1 and SSME #2, was seen to contact the port side of the vertical stabilizer at SSME ignition (14:48:55.569 UTC). No damage to the vertical stabilizer was visible. No damage was found on the vertical stabilizer at the point-of-contact on the post landing inspection conducted at KSC. This object was probably a hydrogen ignitor spark and not debris. No follow-up action was requested.

2. Summary of Significant Events

2.1.1.2 Purge Barrier Material Seen Near LH2 TSM T-0 Umbilical Lines (Camera: E18)



Figure 2.1.1.2 Purge Barrier Material Near LH2 TSM T-0 Umbilical Lines

A piece of purge barrier material, with attached tape, from the LH2 TSM T-0 umbilical housing was seen near the LH2 TSM T-0 umbilical lines at SSME ignition (14:48:55.820 UTC). No follow-up action was requested.

2.1.2 Debris Near the Time of SRB Ignition

As on previous missions, multiple pieces of debris were seen near the time of SRB ignition. No follow-up action was requested.

2.1.2.1 Debris Contacts the Left Inboard Elevon and Body Flap (Cameras: E13 and E31)

A single long, thin piece of debris appeared to contact the underside of the left inboard elevon at liftoff (14:49:00.700 UTC). The debris was first seen near the LSRB flame duct near holddown post M-6 (14:49:00.240 UTC). A second piece of debris from the ET/Orbiter umbilical area was seen to glance off the body flap at liftoff. No damage to the launch vehicle was noted. No follow-up action was requested.

2. Summary of Significant Events

2.1.2.2 RSRB Flame Duct Debris

(Camera: E1, E3, E5, E7, E10)



Figure 2.1.2.2 RSRB Flame Duct Debris

Multiple pieces of SRB flame duct debris were seen near the base of the RSRB at liftoff. One relatively large piece appeared to travel close to the Orbiter body flap (14:49:00.593 UTC). A linear shaped, dark colored, flexible piece of debris traveled from the RSRB flame duct toward the Orbiter left wing before disappearing behind the left TSM. None of the debris was seen to contact the vehicle. No follow-up action was requested.

2. Summary of Significant Events

2.1.2.3 Debris Contacts LH2 Umbilical Door Sill at Liftoff

(Camera: OTV109)

A single piece of debris (probably ice) fell from the ET/Orbiter LH2 umbilical and contacted the umbilical door sill at liftoff (14:49:00.674 UTC). No tile damage was seen. Debris contacting the umbilical door sill has been seen on previous missions. No follow-up action was requested.

2.1.2.4 Debris Seen Near RSRB Holddown Post M-3 at Liftoff

(Camera: E10)

A small piece of dark debris was seen to fall from the RSRB holddown post M-3 foot area at liftoff (14:49:00.788 UTC). The debris did not appear to originate from the DCS. No follow-up action was requested.

2.1.3 Debris After Liftoff

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) after liftoff on the launch tracking views. The debris was probably Reaction Control System (RCS) paper and ice from the ET/Orbiter umbilicals. None of the debris was seen to contact the launch vehicle. No follow-up action was requested.

2.1.3.1 Debris Seen in Exhaust Cloud after Liftoff

(Cameras: OTV141 and OTV171)

Several pieces of debris, one linear shaped, were seen in the exhaust cloud after liftoff (14:49:02.072 and 14:49:11.385 UTC). No follow-up action was requested.

2.1.3.2 Debris Seen Near LSRB

(Camera: E52)

A single piece of debris was first seen near the aft section of the LSRB and fell along the LSRB plume (14:49:13.832 UTC). No follow-up action was requested.

2.1.3.3 Multiple Pieces of Debris Seen Near RSRB Exhaust Plume

(Camera: E54)

Multiple pieces of debris (possibly SRB aft skirt instafoam) were seen near the RSRB exhaust plume (14:49:20 - 14:49:24 UTC). No follow-up action was requested.

2.1.3.4 Multiple Pieces of Debris Seen in SSME Exhaust Plume

(Cameras: E213 and E222)

Multiple pieces of debris (probably RCS paper) were seen in the SSME exhaust plume after liftoff (14:49:22, 14:49:25, 14:49:27, 14:49:34 UTC). No follow-up action was requested.

2.1.3.5 Debris Seen Aft of the Body Flap

(Cameras: E213 and E222)

Debris (possibly umbilical purge barrier material) was seen aft of the body flap at 14:49:30.649 UTC. No follow-up action was requested.

2. Summary of Significant Events

2.1.3.6 Debris Seen Exiting the SRB Exhaust Plume (Cameras: KTV4B and ET208)

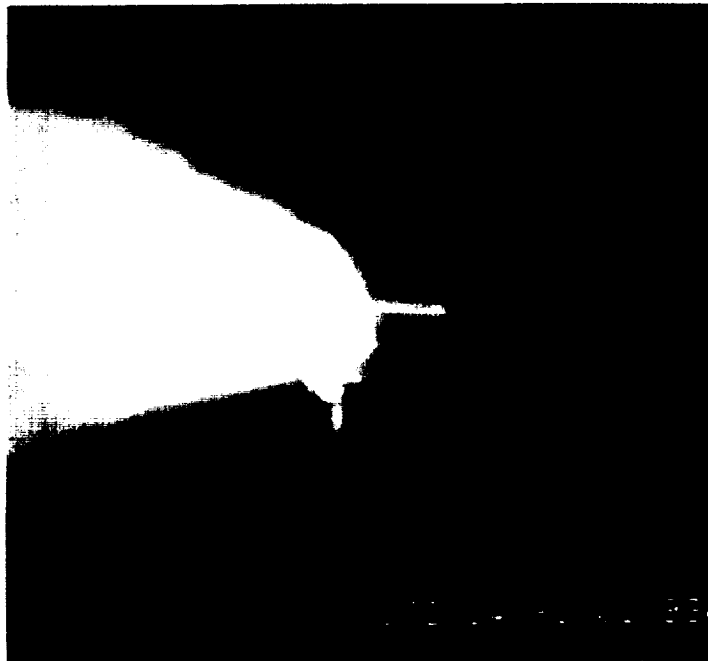


Figure 2.1.3.6 Debris Seen Exiting the SRB Exhaust Plume

A single light colored piece of debris was seen exiting the SRB exhaust plume just prior to SRB separation (14:51:01.930 UTC). Debris aft of the launch vehicle just prior to SRB separation has been seen on previous missions. No follow-up action was requested.

2. Summary of Significant Events

2.2 MOBILE LAUNCH PLATFORM (MLP) EVENTS

2.2.1 Orange Vapor Seen Above the SSME Engine Bells (Cameras: OTV170, OTV171, E16, E62 and E77)

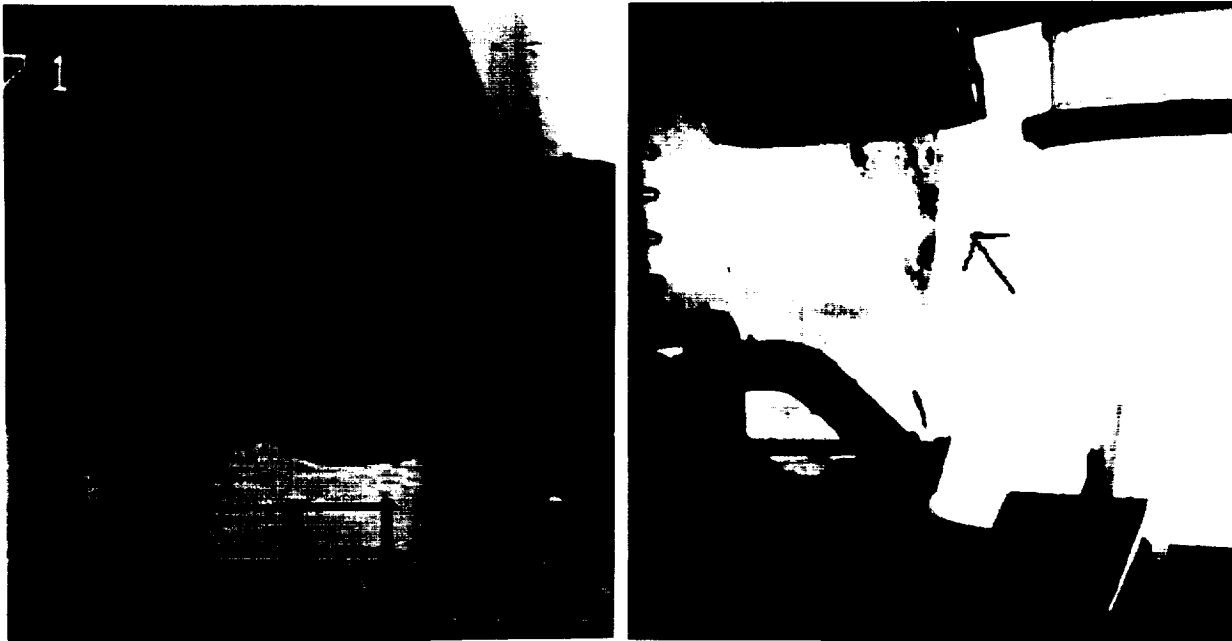


Figure 2.2.1 Orange Vapor Seen Above the SSME Engine Bells

Orange vapor (probable free burning hydrogen) was seen above the SSME rims during SSME ignition (14:48:54.8 UTC). Orange vapors have been seen on previous missions. No follow-up action was requested.

2.2.2 SSME Mach Diamond Formation (Camera: E63)

The SSME Mach diamonds formed in sequence. The times of the Mach diamond formation were:

SSME #3 Mach diamond formation	14:48:56.777 UTC
SSME #2 Mach diamond formation	14:48:56.868 UTC
SSME #1 Mach diamond formation	14:48:57.171 UTC

2.2.3 TPS Erosion on Base Heat Shield (Camera: E18)

Several small areas of TPS erosion were seen on the Orbiter base heat shield near SSME #2 during SSME start-up. The TPS erosion was less than that generally seen on previous mission films. No follow-up action was requested.

2. Summary of Significant Events

2.2.4 Bolt Hang-Up at Holddown Post M-5 (Camera: E12)



Figure 2.2.4 Bolt Hang-Up at Holddown Post M-5

A bolt hang-up was seen near the LSRB holddown post M-5 at liftoff (14:49:00.619 UTC). A curved piece of debris fell from the holddown post shoe Debris Containment System (DCS) area (14:49:00.667 UTC). No follow-up action was requested.

MISSION	LOCATION OF HANG-UP
STS-34	RSRB holddown post M-2
STS-33	RSRB holddown post M-3
STS-39	RSRB holddown post M-1
STS-43	LSRB holddown post M-7
STS-45	RSRB holddown post M-4
STS-50	RSRB holddown post M-4
STS-46	LSRB holddown post M-7
STS-53	RSRB holddown post M-1
STS-73	RSRB holddown post M-2
STS-75	LSRB holddown post M-5
STS-76	LSRB holddown post M-5

Table 2.2.4 SRB Holddown Post Bolt Hang-Ups Seen on Previous Missions

A bolt hang-up occurred at holddown post M-5 on three of the last four Shuttle launches (STS-75, STS-76, and STS-78).

2. Summary of Significant Events

2.2.5 Orange Flashes Seen in the SSME Exhaust Plume (Camera: E3)

Two orange colored flashes were seen in the SSME #3 exhaust plume during liftoff (14:49:01.030, 14:49:01.083 UTC). Flashes in the SSME exhaust plumes have been seen on previous missions. No follow-up action was requested.

2.2.6 Vapors from ET Vents (Camera: E34, E59)

White vapor was seen coming from the ET intertank +ZZ vent during SSME ignition (14:48:56.821 UTC). Vapors were seen coming from the external tank GH2 vent arm port and the ET/intertank -Z vent during liftoff (14:49:02.252 UTC). Vapor from the external tank GH2 vent arm port and the ET/intertank -Z vent have been seen on previous missions. No follow-up action was requested.

2. Summary of Significant Events

2.2.7 ET Tip Deflection Analysis (Task #6) (Camera: E40)

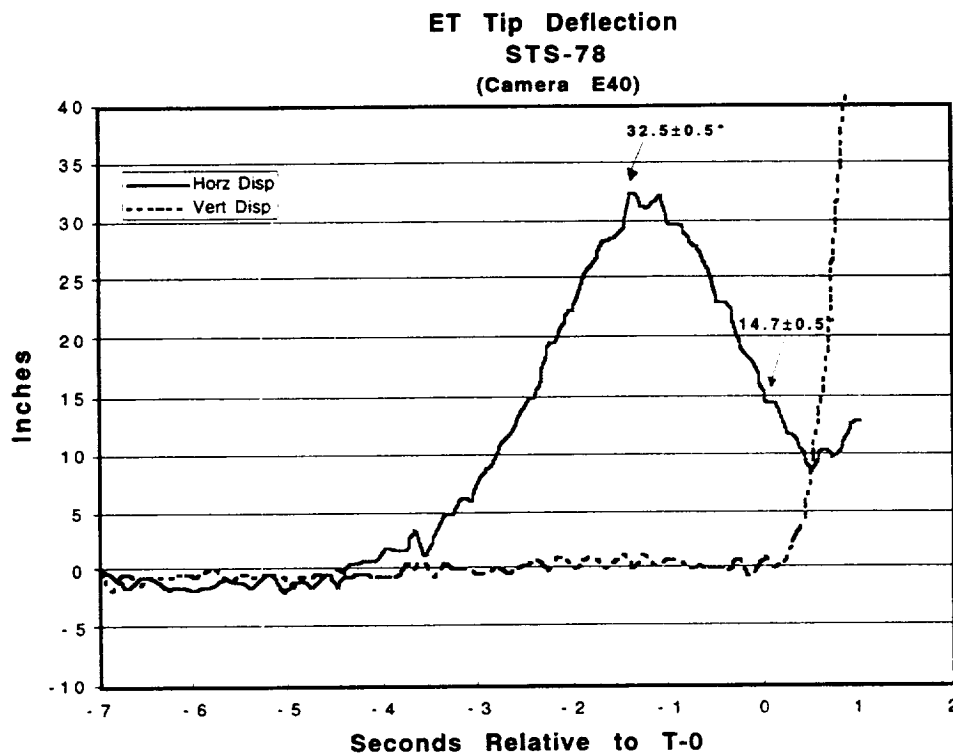


Table 2.2.7 ET Tip Deflection Analysis

To assist in the investigation of the STS-78 SRB heating anomaly, analysis was performed to determine ET tip deflection ("ET twang") during SSME ignition to liftoff. Analysis showed ET tip deflection to be a maximum lateral deflection of $32.5'' \pm 0.5''$ and a tip deflection of $14.7'' \pm 0.5''$ at T-0. The measured maximum and T-0 deflections for STS-78 were within one standard deviation of the deflections seen on previous missions.

2.3 ASCENT EVENTS

2.3.1 Flares in SSME Exhaust Plume

(Cameras: KTV4B, E213, E222 and E223)

Five flares, probably debris induced, were seen in the SSME exhaust plume during ascent (14:49:21.848, 14:49:28.759, 14:49:33.210, 14:49:33.674, and 14:49:44.466 UTC). Flares in the SSME exhaust plume during ascent have been seen on previous missions. No follow-up action was requested.

2.3.2 Flash seen in the SRB Exhaust Plume

(Cameras: ET207 and ET212)

An orange colored flash was seen in the SRB exhaust plume prior to SRB separation (14:50:51.364 UTC). This event may be part of the normal SRB

2. Summary of Significant Events

plume brightening seen prior to SRB separation. No follow-up action was requested.

2.4 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (DTO-312)

2.4.1 Analysis of the Umbilical Well Camera Films (Task #2)

Three rolls of STS-78 umbilical well camera film were acquired: the 16mm film (5mm lens) and the 16mm film (10mm lens) from the LH2 umbilical, and the 35mm film from the LO2 umbilical. The +X translation maneuver was performed on STS-78.

Good coverage of the LSRB separation was acquired. As on previous missions, numerous light-colored pieces of debris (probably insulation) and dark debris (probably charred insulation) were seen throughout the SRB film sequence. Typical ablation and charring of the LH2 umbilical electric cable tray and the -Y ET/SRB vertical strut were seen. Vapor and multiple pieces of light-colored debris were seen near the LSRB aft attach prior to ET separation.

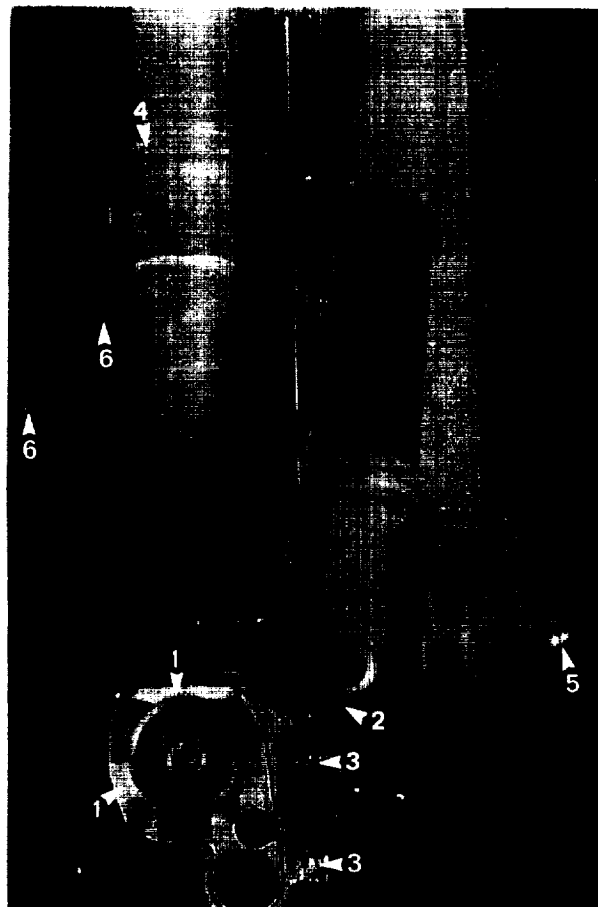


Figure 2.4.1 (A) LO2 ET/Orbiter Umbilical

Good coverage of the external tank separation was acquired. Two of the five lightning contact strips were seen to be missing (12 O'clock and 8 O'clock

2. Summary of Significant Events

positions) on the ET/Orbiter LO2 umbilical interface plate (1). Missing lightning contact strips have been previously seen (as recently as STS-77) and are the subject of a previous mission in-flight anomaly (IFA). The red seal around E0-3 ball joint fitting was seen to be missing (2). TPS erosion/divots were noted on vertical section of the LO2 electric cable tray (3). Chipping of the TPS on the aft two LO2 feedline flanges were noted (4). Possible TPS erosion/divots were seen on the RSRB aft attach (5). Chipping of the TPS on the aft portion of the +Z side of the LH2 tank and TPS erosion on the LH2 tank in the -Y direction of the LO2 feedline were seen (6). The charring of the ET aft dome (caused by aero-heating during ascent) is typical of previous missions.

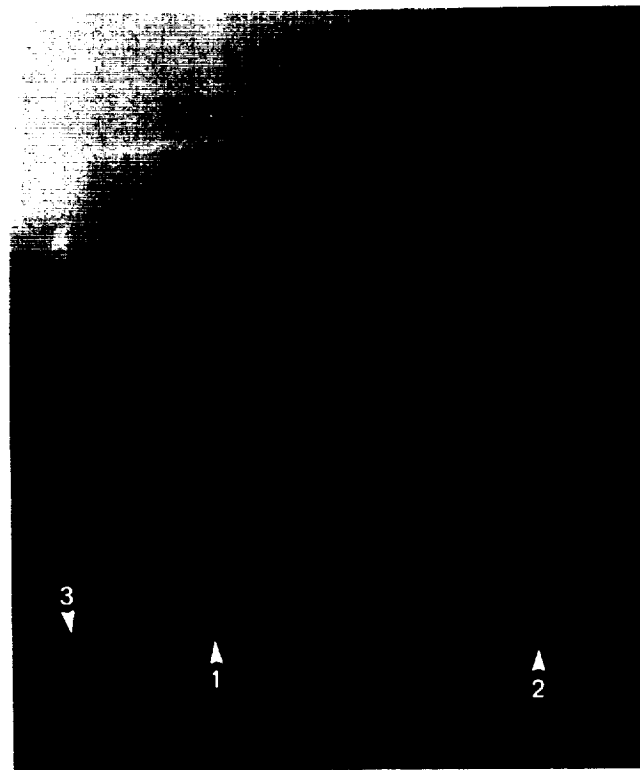


Figure 2.4.1 (B) ET Intertank Area

Divots on the LH2 tank-to-intertank flange closeout under the forward bipod (1) and on the +Y LH2 tank-to-intertank flange closeout were seen (2). Also two small divots in the -Y direction from the forward bipod on the LH2 tank-to-intertank flange closeout were seen (3).

2. Summary of Significant Events



Figure 2.4.1 (C) LSRB Aft Attach Point

Vapor and multiple light-colored pieces of debris were seen near the LSRB aft attach point prior to ET separation (1). TPS ablation was noted on the LH2 ET/ORB umbilical cable tray (2). A piece of white debris (frozen hydrogen) struck the forward surface of the LH2 cable tray (3). No damage to the cable tray was noted.

2.4.2 Analysis of Handheld Photography of the ET (Task #3)

One roll of STS-78 handheld photography was taken using the Nikon F4 with the 300 mm lens plus 2X extender. A DTO-312 pitch maneuver was performed to bring the external tank into view. Thirty-eight usable frames were acquired for analysis.

2. Summary of Significant Events

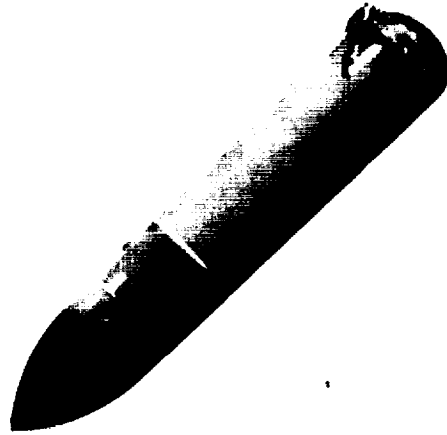


Figure 2.4.2 (A) Handheld View of the External Tank

The first picture was taken approximately 14.3 minutes after liftoff (15:03:17 UTC). All aspects of the external tank were imaged. The external tank appeared to be in good condition on the handheld views.

2. Summary of Significant Events

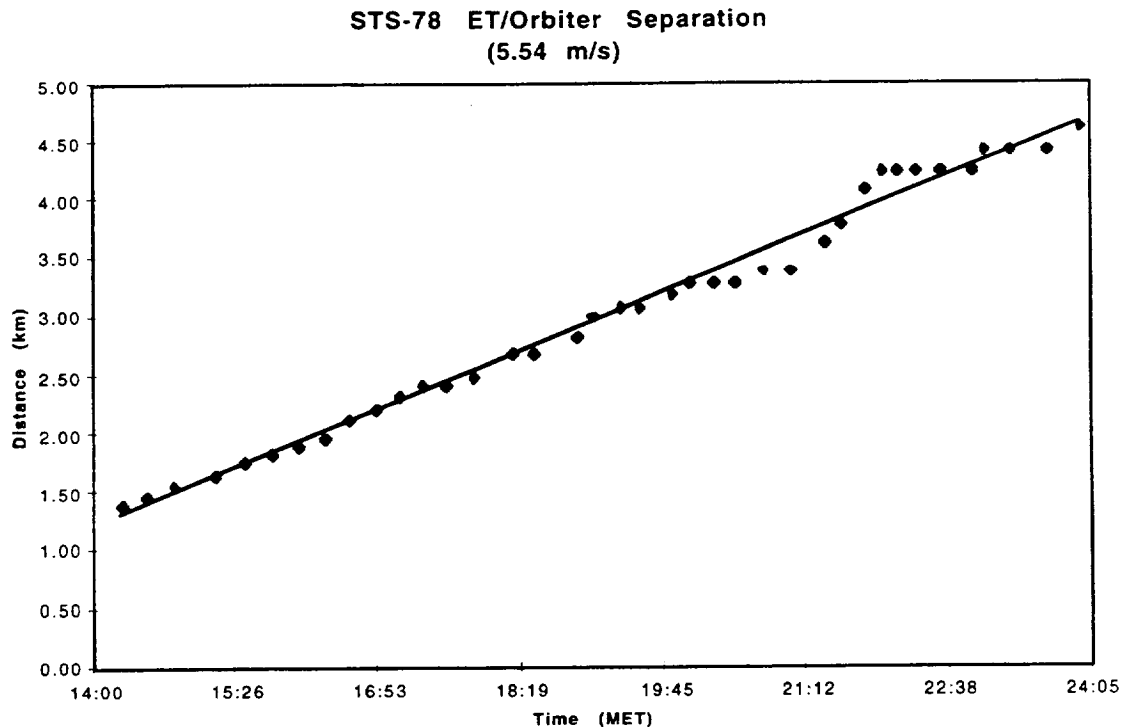


Figure 2.4.2 (B) ET Separation Velocity

The distance of the external tank was calculated over a thirty-eight frame sequence using the hand held photography. The external tank was calculated to be a distance of 1.4 km away from the Orbiter at 14:17 MET. The tank was calculated 582 seconds later (23:59 MET) to be at a distance of 4.6 km. The tank separation velocity was determined to be 5.5 m/s. The separation velocity was similar to previous mission measurements. The tank tumble rate was determined to be 0.7 deg/sec and roll rate was determined to be 0.5 deg/sec.

2.5 LANDING EVENTS

2.5.1 Landing Sink Rate Analysis (Task #1)

The main and nose gear sink rates of the Orbiter were determined using landing film over a one-second time period prior to main gear touchdown.

The measured main gear sink rate values were found to be below the maximum allowable values of 9.6 ft/sec for a 229,200 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS-78 Orbiter was reported to be 221,910 lb.). The sink rate measurements for STS-78 are given in Table 2.5.1. In Figure 2.5.1(A), and 2.5.1(B), the trend of the measured data points for film image data is illustrated.

2. Summary of Significant Events

Prior to Touchdown (1/4 Second)	Sink Rate: Film
Main Gear	1.65 ft/sec
Nose Gear	5.61 ft/sec

Table 2.5.1 Sink Rate Measurements

STS-78 Main Gear Sink Rate From Film
(Camera EL9)

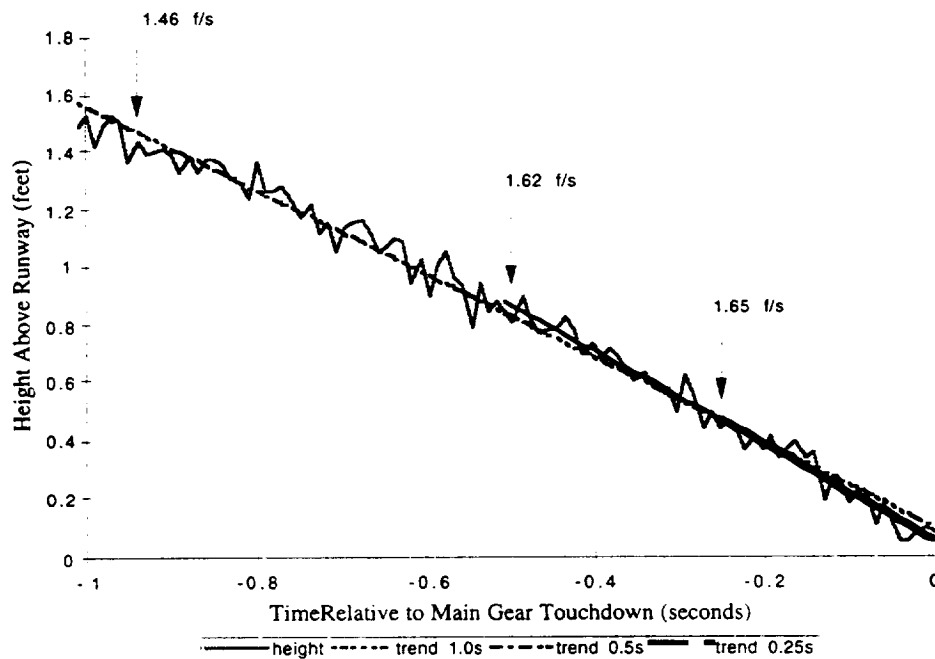


Figure 2.5.1(A) Main Gear Height Versus Time Prior to Touchdown (Film)

2. Summary of Significant Events

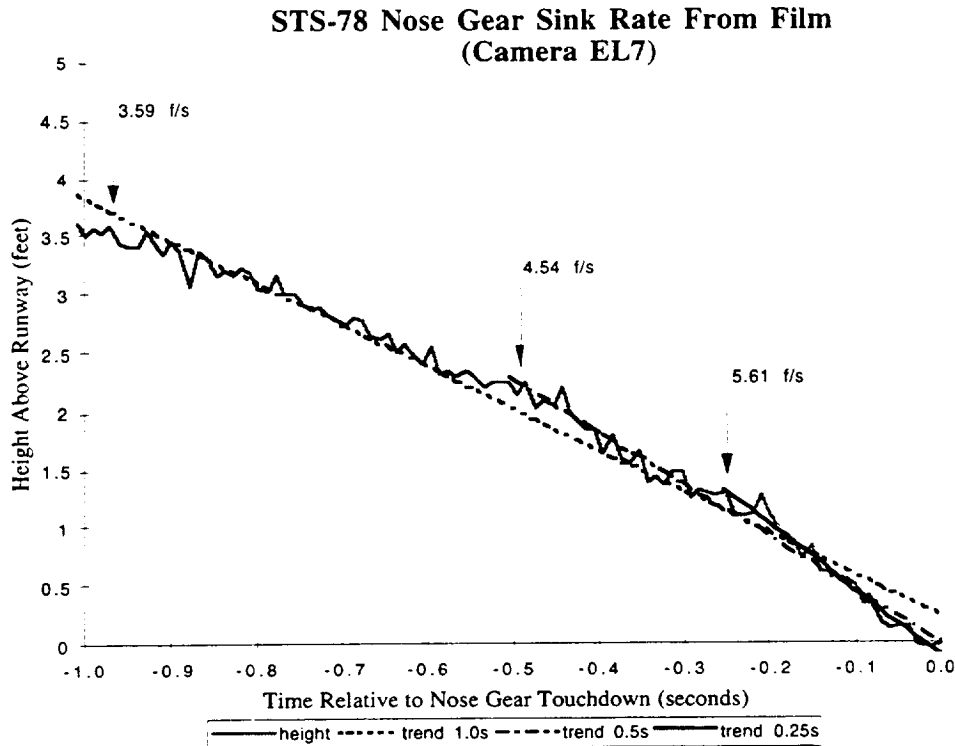


Figure 2.5.1(B) Nose Gear Height Versus Time Prior to Touchdown (Film)

2.6 OTHER

2.6.1 Normal Events:

Other normal events observed include: frost on and around the ET vent louvers, frost on the ET LO2 barrel and LH2 tank acreage TPS (+Y side), ice and vapor from the ET/Orbiter umbilical areas from SSME ignition through liftoff, inboard and outboard elevon motion at SSME ignition, body flap motion during SSME ignition and at liftoff, SRB flame duct and MLP debris at liftoff, ET twang, multiple pieces of light-colored debris falling from the LH2 and LO2 TSM T-0 umbilicals at disconnect, ET aft dome outgassing and vapor off the SRB stiffener rings during liftoff, vapor and ice from the GUCP area during ET GH2 vent arm retraction, vapor from the ET vent louver at liftoff, expansion waves after liftoff, acoustic waves at liftoff, roll maneuver, linear optical effects, ET aft dome charring, recirculation, SRB plume brightening prior to SRB separation, SRB separation, and SRB slag material after SRB separation.

Normal Pad Events Observed Were:

Hydrogen burn ignitor operation, FSS deluge water operation, GH2 vent arm retraction, and MLP deluge water operation, and sound suppression system water operation. J-Pipe water leaks were seen near the RSRB holddown posts M-3 and the LSRB holddown posts M-7 and M-8.

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY



v to Attn of

EP42 (96-26)

July 16, 1996

TO: Distribution

FROM: EP42/Thomas J. Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-78

The launch of space shuttle mission STS-78, the twentieth flight of the Orbiter Columbia occurred on June 20, 1996, at approximately 9:49 A.M. Central Daylight Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Photographic and video coverage was evaluated to determine proper operation of the MSFC related flight hardware.

Film was received from fifty-seven requested cameras as well as video from twenty-four requested cameras. Camera E-212 experienced a film jam and E-223 had a short run. The northern tracking cameras were partially obscured by clouds during ascent. The southern tracking cameras were hazy because of high atmospheric moisture content. Therefore, the data from the long-range tracking cameras was decreased.

Film from the 16mm cameras located in the LH2 umbilical well recorded the SRB separation and ET separation. The astronauts recorded thirty-eight frames of the ET after separation using the hand-help 35mm camera. All surfaces of the ET were imaged with good quality photographs.

The typical events of butcher paper and baggie material falling from the vehicle, debris induced streaks in the SSME plume, and glowing debris particles exiting the SRM plume were noted.

A loose wire or rope was observed near the LO2 TSM umbilical door prior to liftoff.

Venting of white vapors was noted at the ET -Z aero vent prior to liftoff. This venting has been observed on previous missions.

Holddown post M-5 hung up at liftoff. The stud moved in a +Z direction after being released and fell into the hole.

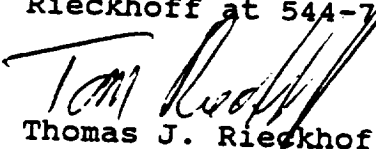
The following event times were acquired.

<u>EVENT</u>	<u>TIME (UTC)</u>	<u>DATA SOURCE</u>
M-1 PIC Firing	14:49:00.028	Camera E-9
M-2 PIC Firing	14:49:00.027	Camera E-8
M-5 PIC Firing	14:49:00.028	Camera E-12
M-6 PIC Firing	14:49:00.029	Camera E-13
SRB separation	14:51:03.72	Camera E-208

This report and additional information are available on the World Wide Web at URL:

<http://photo4.msfc.nasa.gov/STS/sts78/sts78.html>.

For further information concerning this report contact Tom Rieckhoff at 544-7677 or Jeff Hixson, Rockwell at 971-3082.


Thomas J. Rieckhoff

DOI: 10.1002/for

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13. ABSTRACT (Maximum 200 words) A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-78. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs and infrared scanned data during cryogenic loading of the vehicle, followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-78 and the resulting effect on the Space Shuttle Program.					
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